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A MANUAL OF ELEMENTARY BOTANY FOR INDIA

BY

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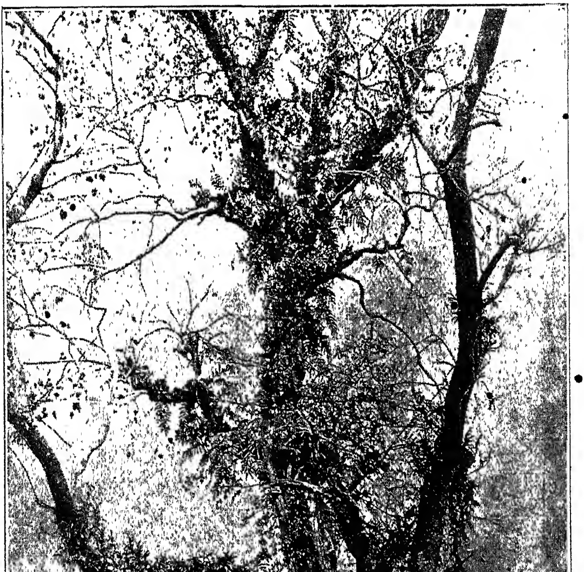
SECOND EDITION
(Revised and Enlarged)

MADRAS
PRINTED BY THE SUPERINTENDENT, GOVERNMENT PRESS

PRICE, 4 *rupees*]
1921



Epiphytes growing on Ficus religiosa.

PREFACE TO THE SECOND EDITION.

ALTHOUGH the first edition of this book was primarily intended for the students of this college, it was used as a text-book in other Professional and Arts and Science Colleges in India. Therefore, with a view to meet the requirements of all these students better, I have extended the scope of this work in this edition by revising certain portions and by adding some more chapters on cryptogams, organic evolution and heredity. I have to express my obligation to Mr. F. R. Parnell for many suggestions and corrections in the chapter on heredity and mendelism.

The scientific names of species, in some cases, have been changed in accordance with *Gamble's Flora of the Madras Presidency.* The additional illustrations are the work of my artist M. Singara Royan. In the matter of proof-reading I had much help from M.R.Ry. P. S. Jivanna Rao, M.A.

I have to thank the Director of Agriculture (M.R.Ry. Diwan Bahadur L. D. Swamikannu Pillai Avargal) and the Madras Government for ordering the publication of this edition of my book.

The excellence of the get-up is due to the interest taken by Mr. F. L. Gilbert, the Superintendent, Government Press, and I am very much indebted to him.

AGRICULTURAL COLLEGE,
COIMBATORE,
1st November 1921.

K. RANGACHARI.

PREFACE TO THE FIRST EDITION.

ALTHOUGH a large number of excellent books on botany are available, they are not so useful for students of this country because the plants referred to in these books are not known to them, nor are they easily procurable. A few books in which Indian plants are dealt with are either too elementary or they cover only certain aspects of plant life. This book, restricted to flowering plants, is intended to meet the requirements of students of Secondary and Training schools, Technical and Professional colleges and of teachers and others interested in botany.

The arrangement of the topics adopted is what I found to be most convenient in practice. Most of the facts contained in this book form the common property of botanists, but the material chosen for the elucidation of these facts is new. The use of a microscope for purposes of demonstration is essential for a clear and correct understanding of the subject, although some deprecate its use even in the preliminary courses of the University in this Presidency. No one would ever try to teach the functions of plants such as absorption, starch formation and respiration without reference to root-hairs, chloroplasts and stomata. Mere mention or even verbal descriptions with diagrams cannot be expected to make points as clear and impressive as the demonstrations of actual things would do. To ensure a clear and correct understanding of even the most simple and fundamental facts of plant life, the use of the microscope for demonstration is an absolute necessity, but its misuse must be prevented and guarded against.

The illustrations were specially prepared for this book. All the line drawings (except figures 176, 205, 209, 211, 221, 222, 226, 228, 229, 230 to 232, 234, 235, 238, 239 to 241, 243, 249, 267, 286, 287, 292 to 295, 298, 338, 350, 351, 355, done by R. Srinivasa Ayyar, artist of the Government Entomologist) were made by my artist M. N. Chinnaswami Pillai, and great credit is due to him for the careful drawings of sections made from under the microscope; the photographs and photomicrographs were taken by me.

I am indebted to Mr. R. C. Wood, M.A., for reading through the greater portion of the manuscript and the proof and also for many useful suggestions. I have also received much help in proof-reading from my Chief Assistant Mr. C. Tadulingam, F.L.S., and from Mr. P. S. Jivanna Rao, B.A., Teaching Assistant, in the preparation of glossary and index to plants. Lastly, I have to express my deep gratitude to Mr. D. T. Chadwick and the Hon'ble Mr. Ll. E. Buckley for encouragement to write the book and the Madras Government for ordering its publication. I must also thank Sir Alfred Bourne and Lady Bourne for encouraging me after going through the earlier chapters of this book in the manuscript.

For the excellence in the get-up of the book I am indebted to Mr. T. Fisher, the Superintendent, Government Press.

COIMBATORE,
1st March 1916.

K. RANGACHARI.

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CHAPTER I

INTRODUCTION

THE science of botany or the study of plants is undoubtedly one of the most interesting branches of study. A knowledge of plants is of the utmost importance at the present day, and at every turn in our life this will be found useful. Our lives and those of all animals are dependent upon the vegetation of the earth, and yet how few of us realize the importance of the part played by plants!

Plants are found everywhere and there is scarcely an inch of the surface of the globe that is not occupied by one or other of the living plants. They are infinitely varied. There are plants of all sizes, from the minutest speck like the bacteria revealed only by the highest powers of the microscope, up to trees assuming gigantic proportions. (See fig. 1.)

In form, plants vary so much that one is justified in wondering why we include them all under one group, the vegetable kingdom. Plants are generally grouped under the two heads, flowering and non-flowering plants. Flowering plants produce seeds and hence they are called **seed-bearing plants or spermaphytes.** Non-flowering plants do not produce seeds and they are known as **cryptogams.**

A plant is a living, growing organism. No one would ever think of denying this fact, and yet this idea is hardly a prominent one with us. Animals have habits of their own; they like certain things and dislike others; they have very often ways of their own; they breathe, feed and reproduce

their own kind, and have to fight with individuals of their class and also with other living beings. Just like animals, plants also have their habits, likes and dislikes, and little ways of their own; like animals they breathe, eat and reproduce their own kind; they also have much to fight against; and they make the most of every opportunity. However, there exists considerable difference between animals and plants, in their mode of living.

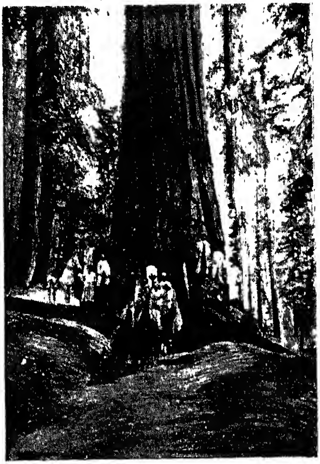

Fig. 1. The main trunk of *Sequoia gigantea*, Lindl et Gord, the Mammoth tree of California. Note the path cut through the trunk. (From a photograph lent by Dr. C. B. Rama Rao.)

Although plants present endless differences in detail, most of them are alike in certain general features of form and structure. A cursory examination of seed plants is enough to convince one of this fact. In a plant body we can distinguish two definite parts: the root which penetrates deep into the soil and the shoot which grows upward into the air. The shoot consists of the stem, leaves, flowers and fruits, and the root has only branches. These are the conspicuous organs of the plant, and they are concerned in the work of nutrition and reproduction.

A plant grows and lives amidst other plants and animals. There are also the physical conditions such as the soil, the moisture, and the temperature. All these constitute the surroundings of the plant. A successful living, on the part of a plant, depends upon the conditions and the relationship existing between it and the factors which constitute its surroundings. Plants get particular shapes and habits, as the result of the interactions between them and their surroundings.

Plants also like animals have to fight against disadvantages which are generally formidable. They have to struggle against animals and other plants. They must also be capable of seizing upon any advantage that may present itself in the air, in the soil and in competition with other plants. Growth amidst very uncongenial surroundings is not possible, because plants are not able to adjust themselves to them. If, on the other hand, the environment is not very uncongenial, the plant adapts itself by modifications in its structure and habit.

CHAPTER II

THE TRIBULUS AND GYNANDROPSIS PLANTS

The Tribulus terrestris plant.—The study of plants is best begun by the examination of some of the common ones. All of you have seen and are acquainted with the Tribulus plant. The scientific name of this plant is *Tribulus terrestris*, L.* It grows everywhere in dry open places and is in flower all the year round. Perhaps you remember the tribulation it causes to those who unwarily tread on it.

Try to pull one of these plants from the ground. It is not quite easy to do so. The difficulty of pulling up the root shows one use of this part of the plant, and that is that the root fixes the plant firmly in the ground and prevents it from being dragged out by the wind. The root-system of this plant consists of a single, thick, long root going straight down, and a few small roots springing from it and running obliquely. The roots are all pale in colour. The stout, leading root is called the **tap-root**, and the others are lateral roots. It must not be supposed that these represent the whole of the root-system of this plant. Very many small roots remain behind in the soil.

The main stem of this plant is in continuation with the tap-root and, rising a little above the ground level, it breaks into a number of branches, running on all sides and lying close to the ground. The **shoot** or the aerial part of the plant consists of several stems, bearing leaves, flowers and fruits. The whole of the shoot-system is green, whereas the root-system is devoid of this colour. All parts of the shoot are covered with close-set, soft hairs.

The most conspicuous feature in the shoot is the presence of a large number of green leaves. At the lower portion of

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* The scientific name of a plant consists of two words. The first word (Tribulus) is the name of the genus and the second (terrestris) is the name of the species. The letter L. stands for Linnæus who first gave this name to this plant.

the branches, the leaves are larger and they get smaller and smaller towards the apex. This is so, because the leaves nearer the base of a branch are older and those nearer the apex younger. In other words, the leaves arise at the tip one after the other in regular succession.

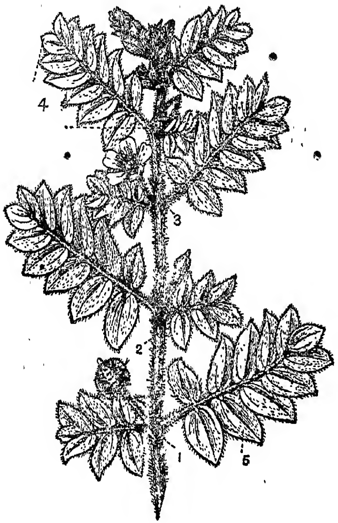


FIG. 2. A branch of *Tribulus terrestris* 1, node; 2, internode; 3, stipule; 4, leaf; 5, leaflet.

In the stem the places where the leaves arise are called **nodes**, and the portion between two successive nodes is termed an **internode.** Towards the growing end of the shoot, the internodes get shorter and shorter, and hence the leaves get crowded. At every node buds are situated in the angles formed by the leaf with the stem. This angle is called the When the bud in the axil develops, it repeats the character of the shoot on which it arises, and so it is called a branch. In flowering plants branches arise generally from the axils of leaves.

At every node in the Tribulus branch, there are two leaves, opposite to one another; one leaf is smaller than the other and sometimes even this small leaf may be wanting. Four small pieces somewhat

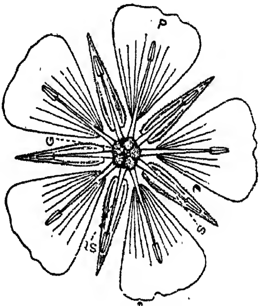


FIG. 3. Parts of the Tribulus flower. S. sepal; P. petal; St. tamen; G. pistil.

triangular in shape are present at every node, one on each side of the leaf. These out-growths from the basal portion of a leaf are called **stipules.**

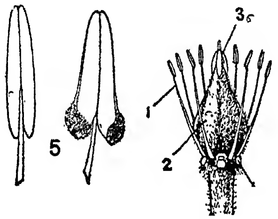


FIG. 4. The essential parts of the Tribulus flower. 1 and 5, stamens; 2, ovary; 3, stigma; 4, gland.

The leaf has a very short stalk called the **petiole** and the leaf blade is cut up into segments, in such a way that one can be taken off, without in the least affecting the other pieces. Therefore the leaf is a **compound leaf,** and the pieces are **leaflets.**

One may be inclined to consider the leaflets as leaves. But we have very good reasons for calling them leaflets. Leaves spring from the nodes; and the stem which bears them either grows beyond them, or gives sufficient proof that it will do so. Leaves commonly die and fall off as a whole, i.e., petiole and all. If these small segments are really leaves, they must fall one after another leaving the axis on the plant, and the axis must have a growing region at its free end. Leaflets, along with the part carrying them fall down, and there is no growing point at the end of this part. We have, therefore, to consider the whole structure, leaflets and all, as forming a leaf. As a rule buds are found in the axils of leaves and, in the axils of leaflets, we do not find any.

Some of the branches may have bright, yellow flowers springing from the axils of leaves. The flower consists of four distinct parts. The most conspicuous ring of yellow leaves is the **corolla**, and the leaves of this whorl are the **petals.** Between and below the petals, we find five narrow structures green in colour. These are called **sepals**, and the whorl of sepals is known as the **calyx.** In the flower bud the sepals form a tight coat. Next to the petals inside, there are ten thread-like things with yellow bodies at their ends, and each of these yellow knobs has two lobes. Five of these threads are long and opposite the petals and the remaining

five are short and opposed to the sepals. These two whorls are the **stamens** and each stamen consists of a stalk or **filament** carrying a knob, called an **anther**, at its tip. The anthers contain a fine powder or **pollen**, some of which may be brushed off easily on the fingers. Still inside, in the centre of the flower, there is a five-lobed conical body which is called the **pistil**. This grows and becomes the **fruit**. The top of the pistil is called the **stigma** and the lower dilated portion is the **ovary**. All the parts of the flower spring from the top of the flower-stalk, in close succession. No buds arise from the axils of the floral leaves.

The next thing to consider is whether all the parts of the flower are essential, or only some of them. If we examine flowers at different stages, we do not find all the parts in all of them. Some may have all the parts, but the petals and the sepals may be in a faded condition and about to fall off. In others these parts may be wanting. But in all the flowers, the pistil is sure to be found. This part, instead of remaining small, grows and, therefore, its size will vary according to the stage of development. The pistil is really a young fruit containing very young undeveloped **seeds**. We must consider the parts directly concerned in the production of seeds as the most necessary and essential parts of a flower. The pistil is clearly one of the essential organs, because it contains the young seeds. Stamens are also essential like the pistil, because the seeds are not formed without their help. If we remove the anthers before the flowers open and discharge the pollen and then cover the flower with a paper bag, the pistil falls down. If pollen is deposited on the stigma, the pistil matures and seeds are formed. Therefore we have to infer that the pollen is in some way connected with the production of the seed. So it is evident that the function of the pollen is to cause the production of the seeds by some action which it exerts after it is applied to the pistil. This action leading to the formation of seeds is known as **fertilisation**, and the transfer of pollen to stigma, **pollination**.

The Tribulus fruit consists of four or five lobes, and it breaks up into as many segments. (See fig. 5.) Each of these segments bears at its back a pair of long spines above

the middle, and another pair of short spines lower down. When transversely cut it is somewhat triangular in shape and there are four to six thin flat ovate seeds in each segment. The hard covering with its spines not only affords excellent protection to the seeds, but also helps the plant in bringing about the dispersal of its seeds. When we are hurt by the Tribulus fruit, while walking with bare feet, we get annoyed and pick the fruit and throw it away. This is exactly what the plant needs and partly accounts for the persistency with which this plant grows everywhere.

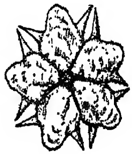


FIG. 5. Fruit of *Tribulus terrestris*, top view.

The Gynandropsis plant.—As another example, we shall examine the plant, *Gynandropsis pentaphylla.* This is a common weed of cultivated and neglected fields. This plant grows erect, branches freely and the root and the shoot systems are very clearly marked.

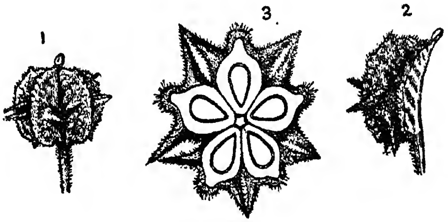


FIG. 6. Fruit of *Tribulus terrestris.* 1, side view; 2, a segment; 3, transverse section.

This distinction into root and shoot is a general character of plants, and it is of fundamental importance.

The root-system of this plant does not differ very much from that of the Tribulus plant. There is a deep seated taproot, as in the Tribulus plant, and it also bears branches.

The shoot-system of the plant, on the other hand, differs from that of the Tribulus in several respects. The branches rise up and grow erect into the air, instead of lying prostrate on the ground as in the Tribulus plant. The leaves

are borne singly at the nodes and they have long petioles. The expanded green blade of this leaf consists of leaflets, but they are arranged in a way quite different from that of the Tribulus leaflets. All the leaflets are at the top of the petiole, and the arrangement recalls to our mind the palmyra leaf. As the disposition of the leaflets is similar to the arrangement of the main ribs of the palmyra leaf, the

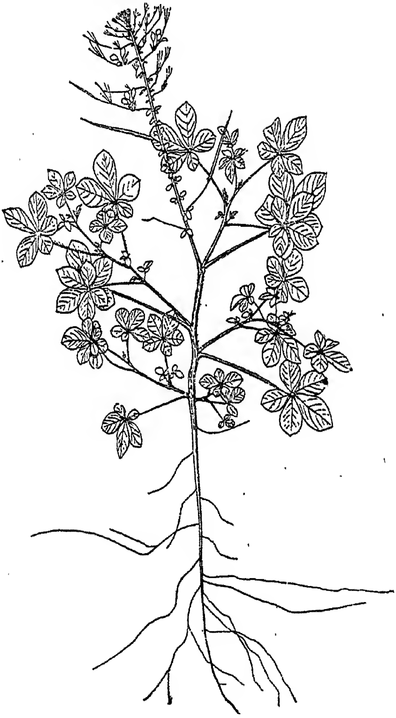


FIG. 7. A complete plant of *Gynandropsis pentaphylla.*

arrangement is called **palmate**; or **digitate**, because the leaflets spread out like the fingers of a hand. The Tribulus leaflets are borne on the stalk like barbs on the feather of a bird, and so the arrangement is said to be **pinnate.**

The flowers are axillary, but the leaves from whose axils flowers spring become very much reduced. All the parts are present in these flowers. The outermost whorl of calyx consists of four sepals and the corolla of the same number of petals. Both these enveloping organs are close together, and they do not hold the most vital relationship to the formation of seeds, which is after all the most important duty of the flower. The essential organs, the stamens and the pistil, stand out very conspicuously, being borne by a stalk. Both the stamens and the pistil are provided with stalks of their own.

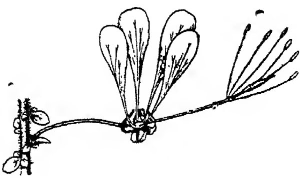


FIG. 8. The flower of *Gynandropsis pentaphylla*.

The Gynandropsis fruit is long and cylindric, and it consists of a wall enclosing a single cavity with three or four rows of seeds.

From a study of these two plants we learn that a plant consists of the six primary parts : roots, stems, leaves, flowers, fruits and seeds. Flowers, fruits and seeds are the parts set apart for the work of **Reproduction**, while the other parts are mainly concerned with **Nutrition**. The roots ramifying and radiating in all directions in the soil secure a firm anchorage for the plant and absorb water which then passes to the stem. The stem bears the leaves and the flowers, and it is the medium through which the raw materials for food pass. The expanded thin green leaves prepare the food needed for the growth of the plant under the action of the sun-light. The showy flowers bring about fertilization, the fruits form the seeds and the seeds, containing each an embryo plant, help in the distribution of plants.

CHAPTER III

THE SEED AND ITS GERMINATION

ALL plants begin their life as **seedlings**, which arise from **seeds.** So we shall examine a few common seeds with a view to learn their structure and then follow the process of germination. The seeds of Tribulus and Gynandropsis, though simple in structure, are not so well suited for the purpose, as the seeds of pulses, e.g., *Cicer arietinum*, *Dolichos Lablab*, *Cajanus indicus*, and *Canavalia*

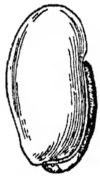


FIG. 9. The profile and broadside view of a seed of *Dolichos Lablab*.

Structure of Dolichos Lablab seed.—The seed of *Dolichos Lablab* is oval, with a smooth surface and a white streak on one of its sides. At one end of the white streak there is a small pit, which is really a minute hole in the seed coat called the **micropyle.** When we press soaked seeds between the fingers, water will be seen oozing out from the micropyle.

Take a well soaked Dolichos seed and remove with a knife the outer covering or the seed-coat. This covering is really divisible into an inner, thin membrane and an outer, thicker firmer one. The whole mass, now-exposed, is the **embryo** or the young plant. On one of its edges there is a conical protuberance, which is called the **radicle.** With the help of a knife or a needle this mass may be separated easily into two large fleshy bodies, or **cotyledons** (seed-leaves) which are not completely separate from each other, but are connected at the side with the radicle. The end of the radicle fits into a hollow cavity, in the seed-coat, exactly opposite the micropyle. Although the cotyledons fit very closely together, they come apart without tearing, as they are naturally separate.

The structure to which the cotyledons are attached is called the **primary axis,** which by subsequent growth,

develops into a seedling and then, into an adult plant. This axis is really the embryo plant. In it we recognize all the parts of the young plant with the exception that nothing comparable with the cotyledon occurs in the growing adult plant. The cotyledons are really leaves containing reserve foodstuff for the use of the embryo plant when it starts life and begins to grow. The curved end of the primary axis above the insertion of the cotyledons is the **plumule** and the part below the point of attachment is the **radicle.** The plumule consists of a very short piece of stem, on the top of which is the **bud.**

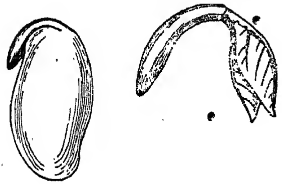


FIG. 10. The embryo and the primary axis in the seed of *Dolichos Lablab.*

Germination of Dolichos Lablab seeds.—When seeds are sown, they soon show signs of life. This manifestation of life is very striking, and changes in form and size take place very rapidly during germination. The early stages in the process of germination can be observed with ease by soaking *Dolichos Lablab* seeds (or other seeds) in water, until they are soft, and then allowing them to germinate in damp sawdust or coconut fibre. The seeds may be taken out, a few at a time, at short intervals, for noting the progress in the process of germination. The process of germination is rapid, if the seeds are kept in a warm room, but even then, some time will probably elapse, before much change is noticeable in them.

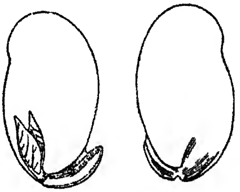


FIG. 11. The embryo of *Dolichos Lablab* seed with one cotyledon removed.

The embryo plant in the seed generally undergoes a period of rest, although this is not absolutely necessary. However, it begins to wake up as soon as it is placed under suitable

conditions. When placed in the soil seeds absorb water very rapidly. The gradual absorption of water by seeds is a very interesting process. Place some seeds in water and observe constantly for half an hour and, after that, at frequent intervals. Note whether the soaking affects the size, colour and texture. Does the seed-coat wrinkle? If so, the wrinkles indicate the places where water has entered and the way it spreads inside the seed-coat. The wrinkling commences near the white streak and so it is obvious that water enters, at first through the micropyle, though later on the entire surface of the seed-coat may absorb it. Further, the line of soft material which runs the whole length of the seed on one side absorbs water very rapidly.

FIG. 12. Seeds of Canavalia showing the wrinkling of the seed-coat.

The cavity into which the radicle fits gets filled with water at the very outset. This water comes into contact with the radicle which grows first, and also very rapidly. The part of the seed-coat beneath the hilum stores up a considerable amount of water for the benefit of the developing embryo. Then the seed-coat and the embryo absorb plenty of water and, in consequence, the seed becomes larger and softer. It is only after this swelling has happened that the seed begins to show any sign of germination. The swelling of the seeds exerts a considerable amount of pressure. The force exerted by swelling seeds is several hundred pounds. So this force is sometimes utilized in separating the pieces of the skull. Dry eeds are put into the skull so as to fill the cavity fully and

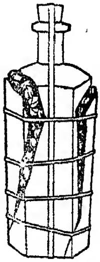


FIG. 13. A glass bottle burst by the swelling of Bengal gram seeds.

when they are moistened the bones are forced apart. This fact can be demonstrated by filling a narrow-mouthed glass bottle with seeds that will just pass through the mouth and placing it in a vessel containing water. After some hours or the next day the seeds will have burst the bottle. (See fig. 13.)

Thus it is obvious that one of the functions of water is to be useful in a mechanical way. It is water that brings about the rupture of the seed-coat and helps the seed to overcome the resistance offered by the soil particles.

The amount of water that seeds, such as *Dolichos Lablab* and other pulses, can absorb is surprisingly large. *Dolichos Lablab* seeds absorb from 95 to 130 per cent of their own dry weight of water; Bengal gram seeds absorb 104 to 110 per cent and Horse gram from 95 to 107 per cent.

Under the influence of moisture and warmth the embryo in the seed begins to unfold its parts. Somewhere close to the micropyle the radicle makes its appearance breaking through the seed-coat, and grows downward towards the centre of the earth, whatever may be the position of the seed.

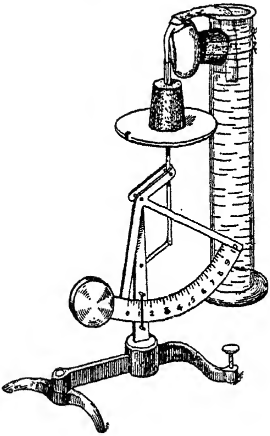


FIG. 14. Seedling fixed to a letter balance.

As the growing radicle or root has to penetrate the soil which is generally hard it should be capable of exerting a considerable amount of force. Some idea of the amount of this force can be obtained by a simple experiment. Fix by means of sealing wax or glue to the centre of the pan of a portable letter balance a cork with a cavity scooped out in it. The cavity in the cork should be well lined with clean moist cotton-wool and a seedling of Canavalia or Dolichos fixed as shown in the figure. (See fig. 14.) As the growth of the

root proceeds the scale-pan will be pressed downwards and the pressure may be read off by means of the pointer.

In germinating seedlings the root grows in length at first and the lateral roots appear only later. This ensures the firm anchoring of the seedling. The next striking feature in the germinating seedling is the elongation of the part of the axis below the cotyledons by rapid growth. At this stage the cotyledons are still enclosed by the seed-coats and so the part of the axis below the attachment of the cotyledons (**hypocotyl**) assumes the form of an arch. The looped hypocotyl by its growth breaks through the soil dragging along with it the cotyledons and the plumule within. This part gradually straightens itself and the cotyledons come out of the seed-coat. The escape of the cotyledons from the seed-coat is important, because the plumule has to find its way out, to grow into the shoot. In seeds in which the cotyledons do not come out of the seed-coat, the plumule emerges through a narrow slit between the stalks of the cotyledons, as in the seeds of Bengal gram, Mango, and *Calophyllum inophyllum*. (See fig. 17.)

From the commencement of germination up to the time, when the first green leaves are unfolded, the seedling depends upon the cotyledons for its food supply. At first the cotyledons are fleshy and thick, but as the radicle and the plumule grow, they become softer and thinner and ultimately shrivel up. These, though considered as the first pair of leaves, are thick because they are packed with food for the rest of the growing embryo. Water so eagerly and largely absorbed by the seed, as soon as it is sown, is useful at the very outset to cause the swelling of the seed and later it is used to convey food from the cotyledons to the various parts of the seedling, where growth is actively taking place.

For germination the first condition that is necessary is the supply of water to the seeds. This fact is obvious from our every day experience.

So long as seeds are dry they remain dormant. A saturated atmosphere is not capable of rousing the seed into activity. An actual contact with liquid water is necessary for germination. An adequate amount of warmth is also necessary.

When seeds are sown in a flower pot surrounded by ice they do not germinate. They also fail to germinate when placed under high temperatures. For every kind of seed there is a minimum, optimum and maximum temperature for germination and the limits vary.

Access of fresh air to the germinating seeds is another essential condition. The need for oxygen is not so much recognized by us as the other two conditions. But when we place soaked seeds in a bottle containing carbon dioxide or hydrogen gas, they do not germinate, although there may be sufficient warmth and moisture.

Seeds fully immersed in water do not at all germinate whereas partly submerged seeds do. In the former case air is completely excluded but in the case of the latter air is available for the seeds.

Respiration of germinating seeds and seedlings.—The behaviour of the embryo during the process of germination and its dependence on the supply of oxygen for successful growth are sufficient indications that we are dealing with living organisms. This becomes all the more apparent, when we observe that the oxygen of the air is absorbed and in its place carbon dioxide is found. And this is exactly what happens in the breathing of an animal. All plants, like animals, must respire so long as they continue to live. During the process of respiration heat is produced both in animals and plants. But the heat produced during the process, in the case of plants, is lost rapidly on account of the very large surface they possess.

That germinating seeds are actively respiring may be demonstrated by means of a very simple experiment. Secure two bottles with wide mouths or conical flasks. Place inside one of them a few germinating seeds of *Dolichos Lablab* and close it with a well fitting cork or rubber stopper having two holes. Close in the same way the mouth of the other bottle or flask, after placing in it some Dolichos seeds killed by boiling or by other means. Insert through one of the holes in the cork a thistle funnel tube, so that the end of the tube reaches almost the bottom of the bottle. Pass into the othe

hole a bent tube so that the end of the tube is on a level with the inner surface of the cork. Close both the funnel and the free end of the bent tube so as to prevent the air from getting into the bottle. (See fig. 15.) After the lapse of a few hours (from 3 to 6 hours) connect the free end of the bent tube with another tube and dip it in a glass vessel containing lime or baryta water. Then pour water into the funnel to drive the air into the vessel of lime or baryta water. As the air bubbles through, the clear water begins to turn turbid and milky. This does not happen in the case of the bottle containing dead seeds. This milkiness is, of course, due to the precipitation of chalk (or barium carbonate) formed by the combination of carbon dioxide with the lime or baryta water, and it is obvious that the carbon dioxide has come from the germinating seeds.

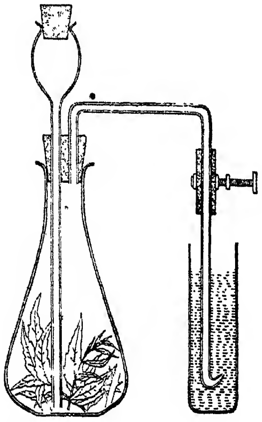


FIG. 15. Apparatus to demonstrate the respiration of twigs or germinating seeds.

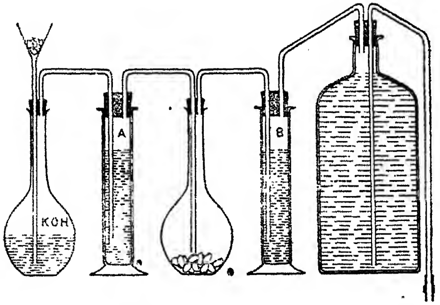


FIG. 16. Apparatus to show that germinating seeds respire.

By using a different set of apparatus it may be shown that germinating seeds give out carbon dioxide even when air freed from this gas is supplied to them. Take a flask provided with a well-fitting rubber stopper having two holes. Place in it a few germinating *Dolichos Lablab* seeds along with a few pieces of clean wet blotting paper. Connect this flask with two cylinders containing lime or baryta water by means of bent tubes as shown in the figure. (See fig. 16.) Next connect the cylinder on the left (A in the figure) with a flask or cylinder containing a saturated solution of caustic potash and solid sticks of the same substance arranged as shown in the figure. The glass cylinder on the right side (B in the figure) should be connected with an aspirator bottle filled with water. All the connexions made by glass tubes and rubber stoppers must be made perfectly air-tight. If water is allowed to flow from the aspirator bottle, air will be drawn in through the bottle containing potash and all the carbon dioxide in the air will be absorbed by the potash. The air thus deprived of the carbon dioxide will get into the flask containing germinating seeds. The lime or baryta water in the cylinder interposed between the seeds and the potash solution remains perfectly clear, whereas the baryta water in the cylinder lying between the aspirator and the germinating seeds becomes milky. After a time the milkiness increases. It is needless to point out that the carbon dioxide has been evolved by the germinating seeds.

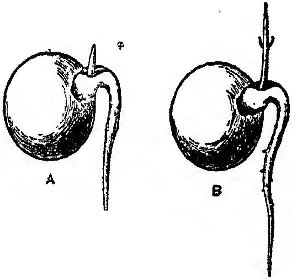


FIG. 17. Seedlings of *Calophyllum*

The process of germination of the seeds of *Dolichos Lablab* described is quite characteristic of most seeds. However we meet with variations, especially in the escape of the parts of the embryo from the seed-coat. So we shall study the germination of some other common seeds.

Germination of Mango, Calophyllum, Cicer and Pumpkin seeds.—In the Mango plant the seed is enclosed by a hard shell which splits on one side and the radicle comes out through the slit. The cotyledons are very large and are so gorged with food stuff that they have lost the power of acting as leaves and are unable to come out of the hard shell. The plumule manages to escape through

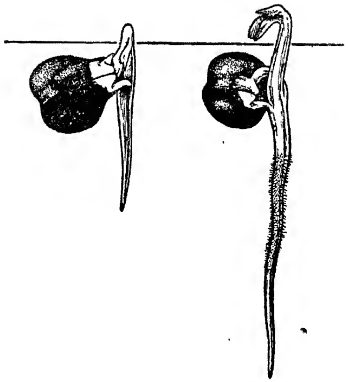


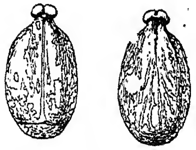
FIG. 18. Seedlings of Bengal gram

a small slit lying between the cotyledons at their base. Another example of this sort is furnished by *Calophyllum inophyllum*. The seed is enclosed by a hard shell as in the case of the Mango seed and the escape of the plumule also is exactly the same as in it. In the Bengal gram seed we have an instance of a seed remaining underground during germination. The plumule alone escapes from the seed-coat, finding its way between the cotyledons at their base. The plumule has in all these cases to come out through a narrow slit, and so the formation of leaves is very much delayed. The first few leaves, therefore, are not well developed ones; they are small, like stipules and are called "**scaleleaves.**"

In the Pumpkin seeds the radicle emerges through a small slit at the narrow end. The cotyledons cannot come out unless the slit becomes wider, because they are large. The radicle developes, close to the narrow end of the seed, a swelling which, like a peg, keeps down the lower half of the seed-coat and the other half is forced upwards by the cotyledons. Then the cotyledons come out, become green, grow and behave like ordinary leaves.

FIG. 19. Pumpkin seedling.

Structure and germination of Castor seed.—The Castor seed presents special features both as regards its structure and the process of germination. The seed-coat is thick, hard and polished, and at one end of the seed is seen a spongy outgrowth **(caruncle)**. The micropyle is not visible as it is hidden by this outgrowth. After removing the seed-coat we find a mass and, if we split this lengthwise in the plane of the flat side, we find a thin leaf-like structure lying flat on each of these massive parts. These are the cotyledons and they are connected with a very



IG. 20. Front and back view of Castor seed.

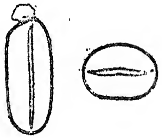


FIG. 21. Transverse and longitudinal sections of Castor seed.

small peg-like structure, the axis. The part on which the cotyledons are lying is something new and it is called the **endosperm**. This is really food stored outside the embryo

and it is intended for its use. The cotyledons are for this

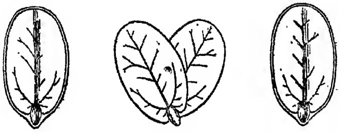


FIG. 22. The embryo of Castor seed with the pieces of endosperm one on each side.

reason thin, and they absorb the food from the endosperm. They remain within the endosperm until all the food store is exhausted and then they come out, expand and behave like green foliage leaves.

FIG. 23. A Castor seedling with the endosperm removed on one side so as to expose the cotyledons.

Structure and germination of Date and Crinum seeds.—The seeds described so far have all two cotyledons and so they are called Dicotyledonous seeds. We have also seeds with single cotyledons and these are Monocotyledonous seeds. As examples of monocotyledonous seeds we may take those of Date and Crinum. The Date seed is very hard and differs in structure from the seeds already studied. On one side runs a deep furrow from one end to the other, and on the other we find a shallow depression, extending from one end of the seed to about its middle where there is a minute pit or cavity. This hollow

is really the micropyle and below this lies the tiny embryo imbedded in the hard endosperm forming the greater part of the seed. If a seed is cut through both longitudinally and transversely so that the plane of section passes through

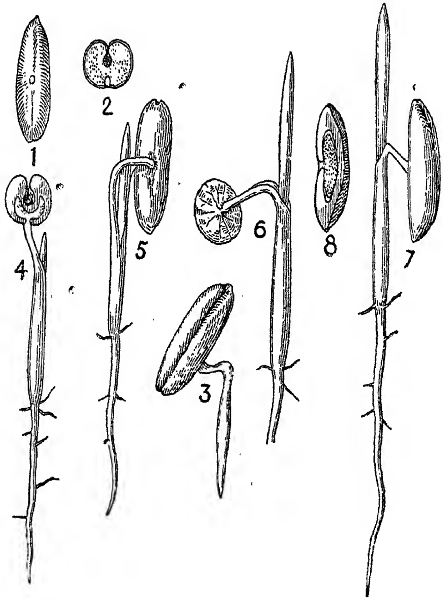


FIG. 24. Date seed and seedlings. 1. Entire seed; 2. see
transversely ; 3, 5, and

the small pit, the endosperm forming the bulk of the seed and the very tiny embryo can both be seen. Its germination is also very striking. As in other seeds, no doubt, the radicle comes out first through the micropyle. After elongating to a certain extent, the radicle becomes somewhat stouter and from the lower end a root is produced. Later on more roots appear from the lower end of the now thickened part, and in its uppe

portion through a slit there appears a stiff growing part, which is made up of young leaves folded one within the other. Thus it is clear that the thickened part is really the primary axis, sheathed by the lower portion of the stalk of the single cotyledon. In the seed the embryo is very tiny and so these parts cannot be made out. During germination the radicle grows rapidly and comes out bringing with it the whole of the primary axis. (See fig. 24.) Further the stalk of the cotyledon also grows aiding the pushing out of the axis. The cotyledon lying in the endosperm increases in size so as to have increased space for absorption. The hard endosperm gets softened as germination progresses. The sheath enclosing the axis and its tip lying inside constitute the cotyledon and its function is to absorb the food stored as endosperm. When the axis enclosed by the sheath or the stalk of the cotyledon is fairly out, the plumule begins to grow and comes above the ground without being injured, as the young leaves are folded one within the other.

The Crinum seed differs from the Date seed in its size, shape and consistency of the endosperm. This is larger, irregular in shape, devoid of seed coat and the endosperm is not so hard. The embryo is small and lies embedded in the endosperm. There is close resemblance between these two seeds in the matter of germination. The emergence and growth of parts of the embryo are similar in all essential respects.

Structure of Maize and other grains.—The Maize grain may be considered next. It is a single-seeded "**fruit**" and not a seed. The embryo lies on one side of the grain, and it may be exposed completely by the removal of the thin skin. The embryo consists of a straight cylindrical axis (the primary axis) and a single cotyledon in the form of a shield folded over the axis. The primary axis is attached at its back to the cotyledon. The plumule is towards the broader end of the grain and the radicle is on the lower narrow side. The free end of the radicle is covered by a special sheath, the **root-sheath**. The cotyledon or the **scutellum** as it is called, is never freely expanded, and one surface of it lies in close contact with the endosperm and,

therefore, acts as an absorbing organ. During germination the radicle comes out first, breaking through the root-sheath, and grows downward, while the plumule with its succession of unsheathing leaves goes upward.

As further examples we may examine the grains of Cholam, Cumbu and Paddy. In all these cases the greater portion of the grain is occupied by the endosperm and the

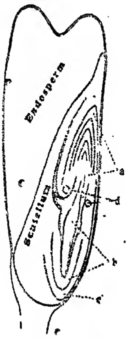


Fig. 25. The Maize grain and its structure. *a*, plumule; *b*, radicle; *c*, root-sheath; *d*, adventitious roots. × 4

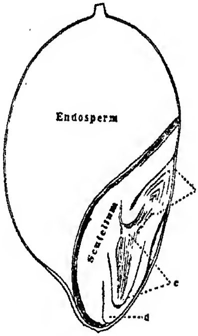


Fig. 26. Longitudinal section of a grain of Cholam. *a*, style scar; *b*, plumule; *c*, radicle; *d*, root-sheath. × 15.

embryo occupies comparatively a very small space. Though smaller in size and different in shape, these are like the Maize in structure and in the method of germination.

Epigeal and hypogeal seedlings.—The emergence of the seedling from the soil is an interesting process. In the case of the Dolichos seedling, as well as in seedlings whose cotyledons come up into the air (and hence called **epigeal**), the part of the axis lying below the attachment of the cotyledons or the hypocotyl, as it is called, grows very rapidly and comes out in the form of a loop dragging along with it the cotyledons and the plumule. The loop being strong is able to pierce through the soil. After sometime the

cotyledons reach the surface of the soil, and then they open to allow the plumule to grow.

There are seedlings whose cotyledons always remain underground **(hypogeal)** and in such cases the hypocotyl never grows; the plumule manages to come out of the seed-coat through a small slit at the base of the cotyledons.

FIG. 27. Longitudinal section of a grain of Cumbu. 1, endosperm; 2, scutellum or cotyledon; 3, plumule; 4, radicle; 5, root-cap; 6, root-sheath. × 20.

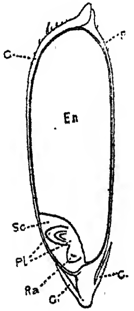


FIG. 28. Longitudinal section of a Paddy grain. *G*, glumes; *P*, palea; *En*, endosperm; *Sc*, scutellum; *Pl*, plumule; *Ra*, radicle. × 5.

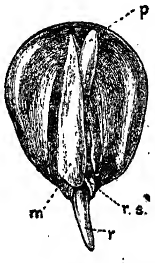


FIG. 29. Maize seedling. *m*, membrane covering the embryo consisting of pericarp and seed-coats; *p*, plumule; *r*, root; *r.s*, root-sheath

(See figs. 17 and 18.) As the plumule has to push aside the soil particles and small stones, its free end is pointed.

Seedlings of Maize and other grains.—The seedlings of Maize and other grains mentioned already and those of Crinum behave in a manner somewhat similar to that of the hypogeal seedlings. The cotyledon in all these never leaves the seed, and the plumule grows out pushing the soil, and this is the reason why the free end of the plumule is pointed. The radicle grows out and the first root bursts the root-sheath and grows downward. New roots arise from the axis and they grow vigorously bursting through the root-sheath and very soon attain the size of the first formed root. In the case of the seedlings of Dolichos, Castor and other seeds that have two cotyledons, all the roots arise from the first formed root and none from the axis. Roots arising from the axis and not thus confined to the first root are called **adventitious roots.** So the roots of the seedling of Maize and other grains are adventitious. New roots

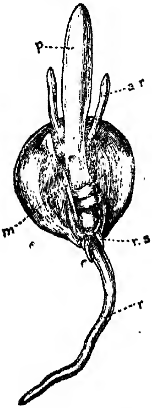


FIG. 30. Maize seedling. *r.* root; *r.s,* root-sheath; *m,* membrane; *a. r,* adventitious-roots; *p,* plumule.

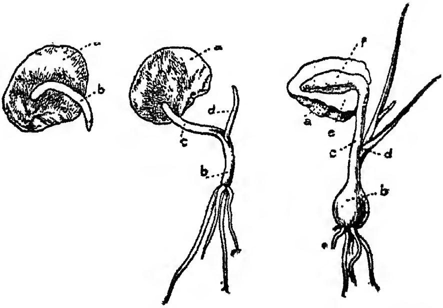


FIG. 31. Crinum seedlings. *a,* seed; *b,* radicle; *c,* stalk of the cotyledon; *d,* plumule; *e,* endosperm; *f,* cotyledon.

make their appearance even in the seed stage in the case of the Maize grain. (See fig. 25.) But in the case of the Dolichos seedlings and others having two cotyledons, the first root invariably gives rise to the whole of the root-system under normal conditions.

Reserve food and structure of Cotyledons.—The food stored in the seed, either as endosperm or in the cotyledons, is mostly in the form of starch. If slices of cotyledons of dicotyledonous seeds and longitudinal sections of any grain are placed in an aqueous solution of iodine, the former become completely blue and in the latter the endosperm alone turns blue. This is the test for starch. The embryo in the seed or grain does not turn blue, and so it is clear that there is no starch in it.

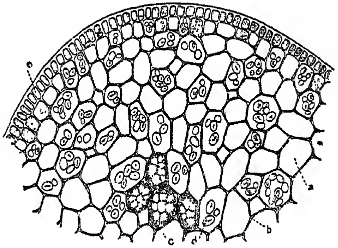


FIG. 32. Section of the cotyledon of *Dolichos Lablab* highly magnified (about 200 times). *a*, empty cell; *b*, cell-wall; *c*, protoplasm; *d*, starch grains; *e*, a layer of cells with dense protoplasm alone without starch grains.

To make out the nature of the reserve food material stored in the seed either in the cotyledons or as endosperm, it is necessary to make use of the microscope. We should take thin slices of the cotyledon or the endosperm and examine them under the microscope. On examining these slices it will be seen that the cotyledons and the endosperm consist of small compartments of various shapes and sizes. These compartments are called **cells.** All these cells will be found to be full of some ellipsoidal bodies. These bodies are the starch grains. Some cells are likely to be free from

these grains, and, by examining such cells, it would become obvious that a cell consists of a firm cell-wall enclosing a cavity filled with some semi-transparent, granular, reticulated substance called **protoplasm.**

The vegetable cell.—All the activities in the living organisms that we observe are due to protoplasm, and so it is sometimes called the "**physical basis of life.**" To make out the structure of a cell and its contents clearly, it would be better to examine under the microscope the hairs found on the young, tender portions of the stem of a Pumpkin plant.

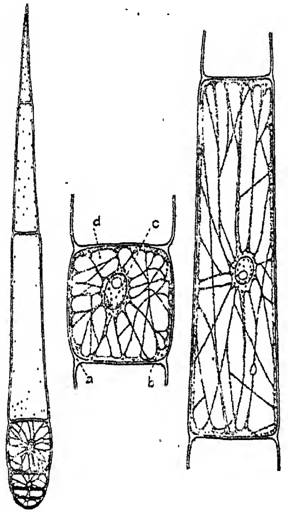


FIG. 33. Cells of the hair of Cucurbita. *a*, cell-wall; *b*, protoplasmic layer; *c*. nucleus; *d*, vacuole. (The hair is × 50 and the cells × 300.)

The appearance of a single hair of this plant is figured here. (See fig. 33.) The appearance of the protoplasm varies with the age and development of the cell. The cells of the hair of a Cucurbita plant figured here may be taken as an example of a typical, fully grown, mature vegetable cell. Within the cell, the protoplasm is in the form of a net-work. A portion

of this substance remains as a continuous layer lining the interior of the cavity and adhering closely to the cell-wall without leaving any space. Several threads, some fine, others coarse, are stretched across in various directions from the layer lining the cell-wall. The spaces within the protoplasm are filled with cell-sap and these spaces are called **vacuoles.** Somewhere within the cell, either in the peripheral layer, or in the cavity, a somewhat rounded compact body will be

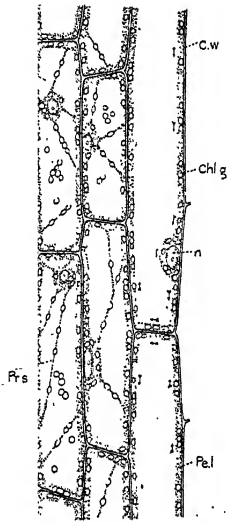


FIG. 34. Cells of the leaf of *Vallisneria spiralis*. *chl. g*, chlorophyll grain; *c.w*, cell-wall; *n*, nucleus; *Pe.l*, peripheral layer of protoplasm; *Pr.s*, protoplasmic strands; *Va*, vacuole. × 150.

seen. This body is called a **nucleus.** From the nucleus several strands run to the peripheral layer. As further examples for cells showing the protoplasm to the best advantage, the staminal hairs of Cyanotis and the longitudinal sections of a fresh leaf of *Vallisneria spiralis* may be examined. (See figs. 34 and 35.)

As has been pointed out already the major portion of the reserve food stuff stored in most seeds is starch. In the seed we do not find starch in the embryo, although there is plenty of it in the endosperm or the cotyledons. But soon after germination we find starch in the axis of the seedling. So it is evident that starch has somehow been transported to the axis. This substance cannot be transported as such, because it is insoluble in water. Unless this is rendered soluble in water it cannot pass into the

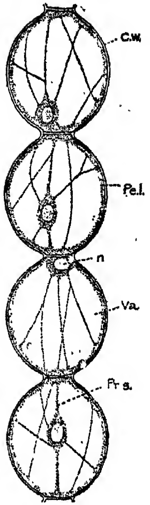


FIG. 35. Cells of the staminal hair of Cyanotis. *c.w.*, cell-wall; *n*, nucleus; *Pe.l*, peripheral layer of protoplasm; *Pr.s.* protoplasmic strand; *Va.* vacuole. × 150.

The protoplasm in the cells of the cotyledons remains in a dormant condition, until water has access to it. As soon as water comes in contact with it, it wakes and begins to show its activity.

Water, as already pointed out, assists the seed during germination mechanically. It also acts chemically. The ferments formed in the protoplasm are at first dissolved by it and then other substances are also dissolved in it to facilitate translocation to other parts of the embryo. When once the protoplasm begins to be active it continues to be so without stopping until the cells become dead.

One of the results of the activity of the protoplasm is the formation of a peculiar substance called **diastase.** This substance has the power of converting starch into a soluble sugar. During germination the protoplasm in the cells of the cotyledons produces diastase, and this acts on the starch grains and corrodes them little by little converting them into sugar. If we examine the starch grains in the neighbourhood of the cotyledons in the Maize or other grain, we find several of them corroded. (See fig. 36.) The sugar thus formed from the starch by the action of diastase passes as a solution, from cell to cell, until it reaches the cells in places where

growth is taking place. The cells in the actively growing radicle and the plumule use up this sugar, to make good the loss due to the process of respiration.

FIG. 36. Starch grains from the endosperm of the Maize grain. A, entire grains ; B, corroded grains. × 300.

A plant, like other living organisms, needs proteids to grow and so, besides starch, it should be supplied with this substance. In all seeds, in addition to starch, there will be found some amount of proteid stored in the form of small or large grains. In most cases it lies side by side with starch

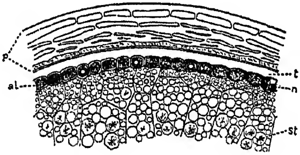


FIG. 37. Aleurone layer in the grain of Cholam. *St*, starch ; *al*, aleurone layer ; *t*, testa ; *n*, nucleus ; *p*, pericarp. × 150.

as minute particles, and then it can be detected only by special means. Sometimes the substance is confined to a special layer of cells lying outside the endosperm, especially in the case of grains. This layer is termed the **aleurone layer,** because the proteid masses are called **aleurone grains.**

The aleurone grains are particularly striking in the endosperm of the Castor seed. They exist as oval or round bodies, varying in appearance according to the medium in which they are mounted for observation under the microscope. When the section of the endosperm is mounted in oil the aleurone grains appear as transparent ovate bodies ; a small rounded body is seen either at one end or on it, as shown in

the figure. (See the three cells to the left in fig. 38.) If viewed in water then within the body a crystal is seen. This is really the proteid. (See the three cells to the right in fig. 38.)

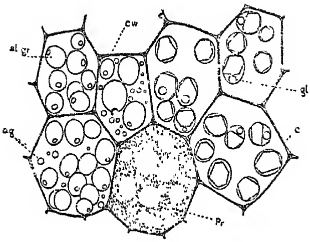


FIG. 38. Aleurone grains in the endosperm of Castor seed. *c.w*, cell-wall ; *cr*, protein crystal ; *gl*, globoid ; *al.gr*. aleurone grain ; *o.g*, oil globules ; *Pr*, protoplasm.

The reserve food does not always take the form of starch. It may be stored in various forms. In the Castor seed it takes on the form of an oil ; it may be stored as sugar ; and in rare cases it is stored even as cellulose, a substance of which the cell-walls are composed. This is the case in Date seeds.

From the study of the structure of the seed, it is obvious that its main function is the production of the embryo along with a supply of food sufficient for the development of the embryo, until it is able to thrive by itself. Soon after maturation seeds of most plants undergo a period of rest. This resting condition is very essential for the preservation of the life of many seeds until favourable conditions for germination occur. It is also probable that ferments are formed in the seed during the period of rest. But sooner or later the embryo must come out of the seed in order to become established as a plant. Examples of seeds germinating while still on the parent plant are not wanting. In many of the cereals very often during wet weather seeds germinate while still in the earheads. Very often we find within the fruits of Papaya seeds in advanced stages of germination. In some trees flourishing in regions of heavy rainfall seeds germinate, while in the fruit either when the

fruit is about to fall or immediately after its fall. The seed of *Hopea parviflora* is of this kind. In Rhizophora and some other mangrove plants the whole of the period of germination is passed on the parent plant without separating from it. The seed of *Rhizophora mucronata* germinates in the fruit and the seedling does not fall down until it has attained a fairly large size. When the radicle has grown to the size of a large cigar and roots have sprung from its end, the seedling drops into the slush.

A seed is generally considered to have germinated when the radicle and the plumule are out, but the process of germination cannot be considered to be completed. The process may be considered completed when the seedling is able to provide for itself food. In the case of small seeds the reserve food would have been depleted by the time the leaves are able to do the work of making food. But in large seeds the reserve material is abundant and more than sufficient to bring the offspring to a position of independence. For example, in the coconut and mango seeds the reserve food does not become exhausted for several months and until several leaves are formed. In these seedlings a fair amount of reserve food remains even after the seedling is able to make its own food.

CHAPTER IV

THE ROOT

ONE end of the primary axis of the embryo bears leaves, and it invariably grows upwards and comes above the ground, whereas the opposite end bears no leaves and it persistently goes downward into the soil. This descending part is the root and the ascending portion is the shoot. The first root is merely the extension of the lower end of the primary axis of the embryo plant: it very soon grows, develops branches, and ultimately there will be a well developed root-system.

The root-system.—To follow the gradual development of the root-system, it is necessary to be constantly examining the root. One of the best methods of observing the gradual growth of the root-system is to sow seeds of different plants in a box provided with a sloping glass on one side. The seeds of *Dolichos Lablab*, Castor, Maize, Groundnut and Bengal gram may be sown with advantage, in the seedling observation box. The roots will grow close to the glass pane in the box, and so their growth may be observed with perfect ease, and without in the least affecting the roots. In the case of *Dolichos Lablab* seedlings growing in this box the tap-root grows downward, and when it is about two inches long, branches arise upon it, similar in all respects to the main root itself, but thinner. The branches grow away from the primary root almost at right angles to it. More branches arise, and these grow out obliquely from their parent roots, and this process of branching may go on until a very extensive collection of roots is produced, which constitutes the **root-system** of the plant.

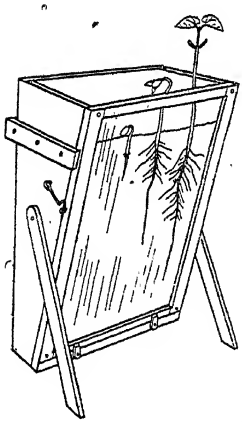


FIG. 39. A seedling observation box with sloping glass front.

The branches in the root-system normally arise in regular acropetal succession. That is to say, in a root the youngest branch will be very near the free end, and the further the branches are from the tip the older they will be. Generally branches form rows around the mother root, and in the tap-root of the *Dolichos Lablab* seedling branches spring from it all round so as to form four longitudinal rows.

In the *Dolichos Lablab* seedlings, as well as in other seedlings, the young tap-root and its branches are covered with downy root-hairs at a short distance behind the young tips.

Differences between shoot and root.—The root-system differs from the shoot-system in several respects. The shoot-system consists of shoots and each shoot has a main axis bearing two kinds of lateral members, branches and leaves. The root-system, on the other hand, consists of a tap-root bearing only lateral roots. The lateral shoot begins as a bud standing in the axil of a leaf, and the axillary bud is a superficial outgrowth from the main axis. Further, every main and lateral branch ends in a bud at the free end. The lateral roots do not arise as buds from

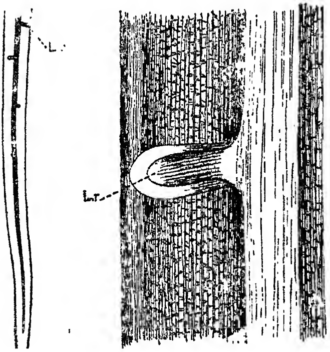


FIG. 40. Section of a root to show the origin of lateral roots. L.r, lateral root.

the outer portion, but they spring from the deep seated parts of the main root and push themselves out. The free ends of all roots are covered by **root-caps**.

Although roots do not bear buds normally they develop adventitious buds when injured. If the old underground roots of a Peepul, Margosa, *Ixora coccinea*, or *Odina Wodier* are severed from the main root, buds spring up from the cut ends of the severed pieces. These are called **root-suckers.**

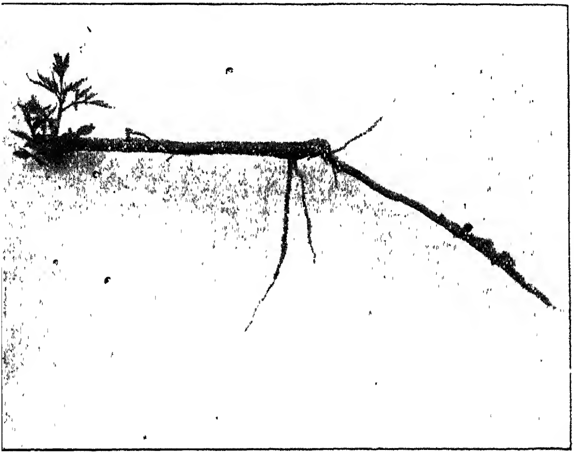


FIG. 41. Root-sucker of Margosa.

Extent of roots.—In most cases, the root consists of a leading tap-root bearing branches. The primary root may be the leading root or its place may be taken up by some other lateral root. The root-systems of plants vary very considerably in extent, and in all cases the total length of the roots is very much greater than what is naturally anticipated. The root-system of a Paddy plant, for instance, will be several yards in length, when the roots are placed end to end. According to the investigations of certain botanists the root-system of an oat plant measured 150 yards in length, although the spread of the root-system was only a cubic yard or two. The root-system of a Pumpkin plant is said by Nobbe to have measured 5 kilometres (about 5,000 yards).

The nature and extent of the root-system depends largely upon its environment. The texture of the soil and the

amount of moisture in it are the factors that affect the development of the root-system. Plants growing in a very compact heavy ground cannot be expected to have a very extensive root-system, but in open loose sandy soil it will be very much larger.

Adventitious roots.—In young plants like those of *Dolichos Lablab* all the roots in the root-system arise from the tap-root and the branches connected with it, and they do not normally spring from other parts. There are, however, a large number of plants that get their roots from parts other than the tap-root. For instance, numerous roots grow from the nodes at the base of the stem of the Cholam plant. All such roots are of the same size and they are called **adventitious** roots. All grasses, plants having underground stems, the Banyan and the Pandanus trees have roots of this sort. Adventitious roots do not arise in acropetal succession. They are best adapted to utilise food materials from the upper layers of the earth, as the roots are small and equal.

Fig. 42. Adventitious roots of *Pennisetum typhoideum*.

Functions of the root.—Plants like other living organisms must take in food to enable them to live. They get their nourishment, partly from the soil and partly from the atmosphere. The most important work the root has to perform is the absorption of water from the soil. To enable the root-system to absorb water, which is one of the most important of the food materials used by the plant, the plant should be firmly fixed in the soil so that it may not be upset easily. This work of anchoring it to the soil effectively, is also one of

the functions of the root-system. All parts of the root-system are concerned in the work of fixation. The tap-root gives support by going straight down and the lateral roots go in all directions around the tap-root and smaller roots also do the same; even the very delicate root-hairs help the root in fixation. The soil particles adhere to the root-hairs so firmly that they constitute numerous holdfasts.

It is easily demonstrable that the root-system is an organ of support. Choose two or three well grown potted plants of about the same height. Cut through the main root of one or two without in any way interfering with the other roots. This will obviously necessitate the planting of a stick or other support to keep the plants erect. For the firm anchoring of the plant in the soil a straight deep root is best suited. Pulling up plants having shallow root-systems is quite easy, whereas deep-rooted plants are very hard to pull.

The other function of the root-system, the absorption of water, becomes obvious if we leave off watering the potted plants and water the plants whose tap roots are severed. In both cases leaves drop off and the plants suffer.

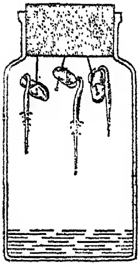


FIG. 43. Seedlings fixed to a cork with roots in different directions.

If the root is to do its function properly it should grow towards and into the soil. The tap-root has always a tendency to go downwards. Pin to the lower side of the cork of a bottle a few seedlings in different directions and replace it as shown in the figure, after pouring some water into the bottle to keep the air moist. After a few hours, the roots in all the seedlings will be seen growing downwards. Change the position of the seedlings at frequent intervals and observe the roots. Even then the behaviour of the roots will be the same. This movement takes place under the influence of gravity.

Roots are also sensitive to moisture. When the roots in their downward and lateral course come to a dry region, they turn away from it and go towards the part of the soil where

there is moisture. In water channels, tanks and wells that do not get dry, we generally see roots in abundance. These roots are those of the trees and shrubs growing in the neighbourhood. As roots are sensitive to water we find roots of plants in wells, rivers and channels. By a very simple arrangement it is possible to demonstrate the sensitiveness to water exhibited by the roots. In a seedling pan place a small flower-pot, right in the middle, and sow soaked seeds in the seed pan all round the flower-pot at a distance of one or two inches. Fill the flower-pot with water. When the seedlings have grown well and have produced one or two leaves, lift the flower-pot and you will see the roots of the seedlings. They all come to the flower-pot because it contains water. For success in this experiment the seedlings should not be watered except when the seeds are sown, and even then very sparingly.

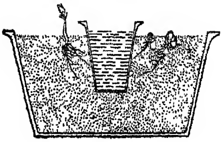


FIG. 44. Arrangement of pots and seedlings to demonstrate the sensitiveness of roots to moisture.

The combined effect of gravity and moisture on the root-system is to make the roots branch well and go in all directions in the soil. Plants that have long tap-roots will last a good while. As the roots produce branches at different heights, they are able to obtain water and salts at different levels.

Further, roots go on growing in all directions, exploring very thoroughly the space traversed by them. So there is not much fear of the plant drying up completely, except during a severe drought.

Roots in order to meet the demands of a plant for absorption and anchorage must go deep enough and spread far enough laterally. A tree would naturally require a deeper and more extensive root-system than a cholam plant. But in all ordinary plants even including some trees the tendency of the root-system is to increase the extent laterally rather than downwards, because more of the requisite mineral matter is available nearer the surface of the soil than deeper down. Further the upper layers of the soil are better aerated than the deeper layers.

The roots of most cereals do not extend to more than four or five feet. Some have roots with greater lateral extension than others. In large trees such as Tamarind and the Rain tree the lateral roots may reach a length of 150 to 200 feet but the depth to which they go is never so much. The lateral roots of these two trees grow along maintaining an average depth of not more than three or four feet. *Albizzia Lebbek* and *Acacia arabica* are examples of trees whose roots go rather deep and sometimes their tap-roots go very deep, twenty feet or more.

The root must have a structure adapted for the work it has to do. All roots have a central region which consists of long, fine, hard stringy pieces. The root has not only to fix the plant firmly but has also to stand much pulling, when strong winds blow the stem on all sides. To be able to resist, the pull a hard central core is necessary. A rope should have a strong core, if it is to be used for resisting a heavy strain or a pull lengthwise. If the central portion were to be weak it would break.

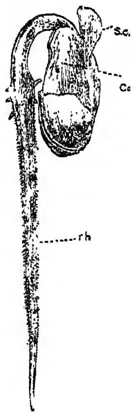


FIG. 45. A seedling with a tap-root covered with root-hairs. *Cot*, cotyledon; *l.r*, lateral root; *r.h*, root-hair; *s.c*, seed-coat.

Internal structure of roots.—The first root, as well as the lateral roots developing later, possesses a growing root-tip. In all roots, whether main or lateral, these growing tips are smooth for a considerable distance. A little behind the growing tips, the roots are completely covered by downy root-hairs to a certain distance; above this region, these hairs disappear and only remnants of dead ones are visible. The actual root-tip is covered by a **root-cap** which consists of a number of layers of cells. In most cases the structure of the root-cap, as well as its presence, can only be made out with the help of the microscope. However, there are a few instances of roots in which the root-cap can easily be seen with the naked eye, as in the aerial roots of Pandanus and Banyan.

The actual tip of the root is composed of small cells, cubical in shape and filled with granular protoplasm, in which is embedded a pretty large round body. This is the nucleus. Wherever we see protoplasm we expect to find this nucleus within it. In the cells found at the growing tips, the nucleus is generally more prominent than in the cells found elsewhere. In these tips of roots division of cells is always taking place. As the cells are always actively dividing in this part it is called the **growing point** of the root. Inasmuch as we find a group of cells all alike in form and doing the same kind of work, we may call these cells of the root-tip a tissue and, as it adds to the number of cells, it is spoken of as **meristem tissue.** Further back the cells become larger in all directions and especially so in the longitudinal direction. The protoplasm filling the cells, instead of being compact, becomes somewhat loose in structure by having a number of small spaces inside. These spaces are called **vacuoles** and the protoplasm is said to be vacuolated. The root-tip, which is smooth and devoid of root-hairs, really consists of the two distinct parts, the **formative region** covered by the root-cap and the **elongating region.**

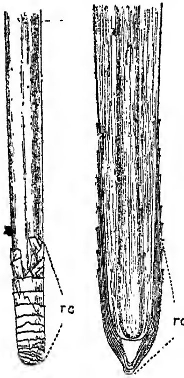


FIG. 46. Root-tip of Pandanus with root-cap *r.c.* The right hand figure is a longitudinal section.

In the formative region of the root the meristematic cells divide and form new cells. Of these new cells those on the side of the root-cap are added on to the inside of it, so that its thickness may be kept up in spite of its being rapidly worn away. Those cells that are on the other side become part of the elongating region.

All the cells in the elongating region grow very quickly in length and this zone merges imperceptibly into the absorptive zone. As soon as the cells attain their average size growth ceases in all cells except the epidermal cells.

These cells instead of growing lengthwise grow outwards in the transverse direction into root-hairs. In the root-hair zone the root-hairs close to the conducting region die off and new root-hairs arise in front, so that the root-hair region may retain its average area and move along with the advancing tip.

The cells of the young root-tip are all living cells filled

FIG. 47. Root-tip of *Setaria italica*. × 50.

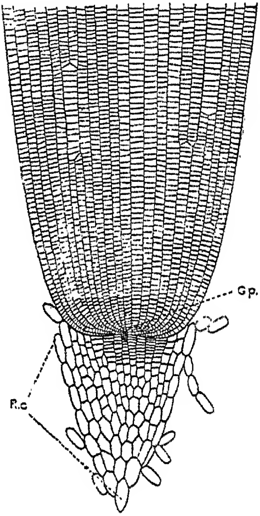


FIG. 48. Root-tip of *Setaria italica* highly magnified. *g.p.* growing point; *r.c.* root-cap. The cells are all shown as empty cells without protoplasm. × 400.

with protoplasm, and so they are in need of oxygen for their growth. For the admission of air spaces are formed between the cells. These spaces appear as dark streaks under the miscroscope between the lines of cells. At first the cells get separated at some point, i.e., at the angles their walls make with each other. These small spaces become united so that intercellular passages run among the cells of every region, and they are of different dimensions in different areas.

These intercellular passages become open to the exterior in the upper portion of the plant. This enables the air to enter and circulate through the interior of the tissues. The openings existing on the bark to facilitate the entrance and the circulation of air are the **lenticels.**

Structure and function of root-hairs.—The root-hairs found on the surface of the root a short distance behind the

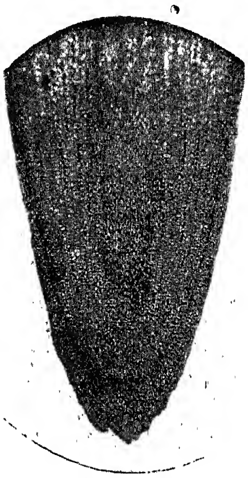


FIG 49. A photo-micrograph of the root-tip. (From a slide prepared by Dr. M. A. Sampathkumaran of Bangalore.)

root-cap are long slender out-growths of the superficial cells. In general, root-hairs have only an ephemeral existence. As the root grows, new root-hairs rise always at the same distance behind the root-tip. Each root-hair consists of a thin wall of cellulose and a protoplasmic layer, and it is brought into close contact with the particles of the soil, as it grows in amongst them. On coming into contact with the soil particles the outer part of the cell-wall becomes changed into a kind of mucilage. So the root-hairs adhere

very closely to the soil particles which are always surrounded by films of water.

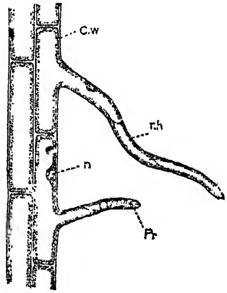


FIG 50. Root-hairs and their structure. *C.w*, cell-wall: *pr*, protoplasm; *n*, nucleus: *r.h*, root-hair. × 400.

Root-hairs vary in length from a fraction of a millimeter to about 10 millimeters and in a square millimeter of space about 300 of them may develop. Although absorption of water usually occurs through the root-hairs, it must not be considered that these are the only organs capable of absorption. The epidermis of the root being non-cuticularized is permeable to water. The advantage derived from the formation of root-hairs is the increase in the permeable surface. Root-hairs tend to increase the absorptive surface five to ten or twelve times. There are also plants whose roots do not possess root-hairs and yet these absorb water. The roots of the coconut tree do not ordinarily bear root-hairs and water is absorbed by these roots through the epidermis. The groundnut plant is another example of a plant which often has no root-hairs in its root-system.

Absorption of water occurs only through the root-hairs. The protoplasm and the water inside the root-hair contain certain substances having a great affinity for water. The cellulose cell-wall of the root-hair is mucilaginous and pervious to water, so the films of water adhering to the soil particles get drawn into the interior of the root-hairs. This absorption of water can take place only under certain

conditions: they are access of air, a certain amount of warmth and of course a suitable supply of water.

All substances that have to pass into and out of a plant cell must pass through both the cell-wall and the protoplasmic layer. Pure water readily passes through both the cell-wall and protoplasm. Many substances may pass easily through the cell-wall, but they may not at all pass through the protoplasmic layer. Further the permeability of the protoplasm, even to any one particular substance, is not the same at all times.

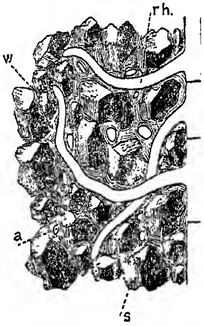


FIG. 51. Root-hairs amidst soil particles. (Diagrammatic.) *r.h*, root-hair ; *w*. film of water ; *a*, air space ; *s*, soil particles.

The water absorbed by the root-hairs passes through the layers lying beneath the root-hair bearing layer (**the piliferous layer**), and reaches the central core of the root. The cells in the central portion of the root are modified into special structures (**vessels**), through which water will pass very readily.

The transformation of the cells into vessels specially adapted for conducting the water absorbed begins in the central portion of the root. In older roots, root-hairs are absent and the conducting tissue (**vessels**) will be abundant and so the older portions of roots have to be considered as mere conducting portions.

To understand the structure of roots and its adaptation to the functions, it is necessary to examine roots at different

heights. As types the roots of Bengal gram, Castor, Cucurbita, Benincasa, Colocasia, Onion, Cholam and Musa, may be examined. The growing regions of roots possess more or less the same kind of structure in all flowering plants. But in the absorbing regions there are differences in structure, and in the conducting regions these differences become still more marked.

FIG. 52. Vessels with different kinds of thickenings. *a*, annular vessel; *b* and *c*, spiral vessels; *d*, reticulated vessel; *e*, pitted vessel. × 400.

In the roots of plants like Cicer, the tissues through which absorbed water is conducted forms a hard central cylinder surrounded by several layers of cells with thin walls, and this portion of the root is called the **cortex.** The cells in the central portion of the roots increase in number and some of these cells become changed into vessels which arrange themselves in definite groups. These groups run longitudinally and are called **vascular strands** or **vascular bundles.**

The structural elements of the vascular bundle.—These bundles consist of various elements. Some are narrow or wide tubes called vessels and others are thick-walled, elongated or short cells. The vessels are formed from the fusion of the superposed cells; the transverse septa of these cells are absorbed and the thin cell-walls become thickened by the addition of some substance in the form of layers on their inner surface. The thickening never takes place uniformly. In a great many vessels the thickening takes place all over the wall, leaving certain thinner places which we may call pits or pores. The thickening may

take the form of a network and in a few vessels the thickened parts are like the rungs of a ladder. There are also vessels with the thickened part in the form of a spiral or isolated rings. Names are given to these vessels according to the nature of the thickening. If the thickening is very pronounced with only a few places not thickened, the vessels are called **pitted vessels**, as the thin areas look like so many pits. The vessels with reticulate thickenings are called **reticulated vessels**. Those with ladder-like thickenings go by the name of **scalariform vessels**; when the thickening is spiral the vessel is a **spiral** one, and if annular it is an **annular vessel**. In a vascular bundle all or some of these kinds of vessels are found and they are all held together by certain fibrous elements which run between them.

If we take the function of the root into consideration we may easily distinguish three distinct zones or regions in the root. They are the extreme tip, the root-hair bearing region and the conducting part. The root-tip is covered at the end by the root-cap, and this is the region where cell division is going on rapidly and also the elongation of the cells. This is succeeded by the zone of the root-hairs, which is the part whose main work is absorption of water. All these regions are not sharply marked off one from the other, but the one runs imperceptibly into the other. In the second absorptive region the beginnings of conductive tissue may also be seen. Lastly comes the conductive region which is really the fully developed portion of the root.

The structure of Cicer root.—We shall now consider in detail the structure of the roots of some of the plants already mentioned. Let us first study the root of *Cicer arietinum*. A transverse section of this root taken through the growing tip will reveal under the microscope two distinct regions, the central core of cells in which the cells are small, though of different shapes, and the broad outer cylinder enclosing the central core. The outer cylinder, consisting of uniform cells all thin walled and in several layers, constitutes the **cortex**. The central core of tissue is called the **stele**. In the growing region of the tip of the root the cells in the stele will be remarkably uniform. In the upper part a few cells may be elongated.

In a section taken through the part where the root-hairs are developed, the stele will show some amount of differentiation. The outermost layer of the cortex gives rise to the root-hairs and so, that layer is called the **piliferous layer.**

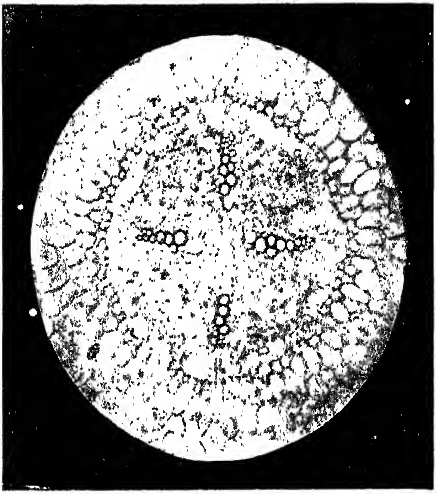


FIG. 53. Transverse section of a very young root of *Cicer arietinum*. The continuous layer of small cells in the form of a ring is the endodermis, and the four groups of thick-walled cells are protoxylem groups. × 200.

All the cells contain protoplasm, except a few thick walled ones which are really the cut ends of vessels. These vessels are confined to the stele and in it they are grouped together in a definite manner. Within the stele we see in the transverse section four distinct groups of thick-walled vessels at equal distances from one another. (See fig. 53.) Of the vessels of these rows, those lying at the periphery of the stele and towards the cortex are smaller and they get gradually larger and larger towards the centre of the stele. From this it is clear that the old vessels are towards the periphery and the new towards the centre of the stele. In other words, the development of vessels in this case is from

the circumference towards the centre. This kind of development is said to be **centripetal.**

The structure of the same root, in a little older portion will be slightly different. The cortex will be quite distinct from the stele or the central cylinder (also called the vascular cylinder, because the vessels appear only within the stele). The innermost layer of cells in the cortex becomes very well marked, and it is termed the **endodermis.** On the

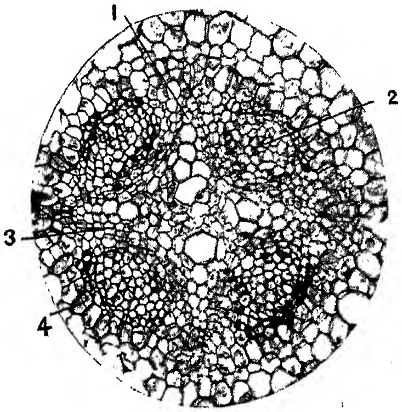


FIG. 54. Transverse section of a very young root of *Cicer arietinum* a little older than in fig. 53. 1, protoxylem; 2, phloëm; 3, cambium; 4, pericycle. × 200.

radial walls of the cells of the endodermis are present small spots, and these are called Casparian spots. The presence of these dots is a general feature of the endodermis. Everything enclosed by the endodermis forms the stele. Within the stele will be seen the four groups of vessels, which have increased in amount, and have by now all met in the centre (see fig. 54). Alternating with these four groups of vessels, which are called **xylem** groups, there exist four masses of thick-walled cells in the stele, though very close to the cortex. These thick-walled cells are really elongated structures and they are called fibres or **sclerenchyma.** Close to the fibre

groups and within the stele we see a few cells irregularly arranged, and varying in size. Some of these are really thin-walled vessels having at intervals perforated transverse partitions. On account of these sieve-like partitions these vessels are called **sieve tubes.** As a large number of sieve-tubes are found together in groups in definite situations, these groups are called the **phloëm.** Close to the phloëm we generally find fibre groups. In the stele the peripheral portion lying in close contact with the endodermis and outside the fibre groups is called the **pericycle.** This layer

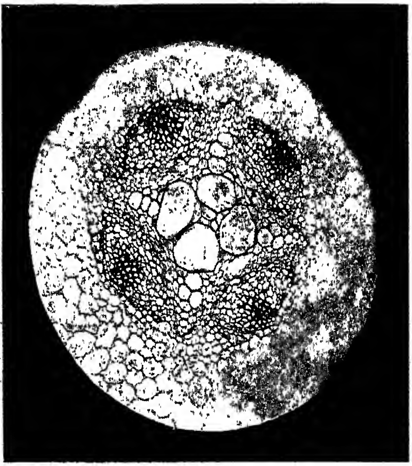


FIG. 55. Transverse section of Cicer root older than in fig. 54. × 110.

is a very important layer in the case of the root, and it consists of a single layer of cells, though it may have in certain places more than one layer. Between the xylem and the phloëm groups there are one or two layers of cells quite regular in arrangement, full of protoplasm, broader than long and standing out very distinctly. These are cells undergoing division, i.e., they are meristematic cells. Such meristematic cells as these are also found on the outside edge of the xylem groups, and they are derived from the pericycle. These

groups of meristematic cells become extended and so we see a continuous ring of meristem. This wavy ring is called the **cambium ring.**

The function of the cambium ring is to produce cells, both inside (towards the xylem) and outside (towards the phloëm). These cells become gradually transformed into xylem elements or phloëm elements, according to their position. The vessels and cells that are brought into existence

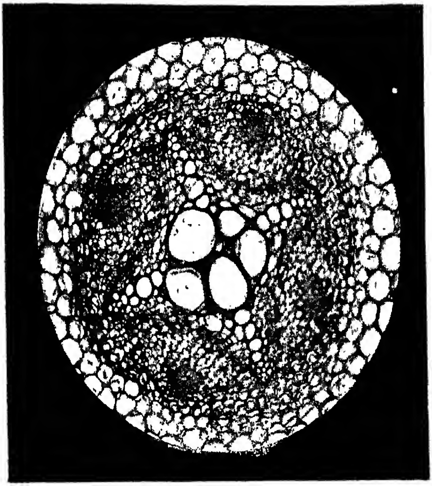


FIG. 56. Transverse section of the root of *Cicer arietinum*, a later than in fig. 55. × 150.

by the cambium ring must be differentiated from the vessels in existence prior to the formation of the cambium ring. All the tissues derived from the original meristen tissue of the growing points are called **primary**, and so the xylem and the phloëm formed in the root before the establishment of the cambium ring are **primary**. The cambium itself is newly produced, by the activity of the mature cells that have become permanent; and so this is **secondary meristem** and not primary. All the tissues originating from the cambial activity should be called **secondary**. Hence the xylem formed by the cambium is **secondary xylem** or wood, and the phloëm is **secondary phloëm**. The development of

the secondary xylem in the root is from the centre towards the periphery, i.e., **centrifugal.**

FIG. 57. Sieve-tubes in longitudinal section. (*Cucurbita maxima* stem.) *Si.t*, sieve-tube; *Si.p.* sieve plate; *Cal*, callus, *C.C*, companion cell.

In older portions of roots the cambium assumes the form of a regular ring and it is a hollow cylinder enclosing a mass of xylem both primary and secondary. The phloëm lies outside the cambium ring. It is surrounded by the cortex which may be decaying. Very soon the cortex wears out, and its place is taken by layers of special cells called cork cells derived from a cork cambium, arising from the pericycle.

From what has been said above, it is obvious that a transverse section of an old root should differ from that of a young root very much in its structure. The cortex with its piliferous layer sloughs off in the older roots, and the function of protection is then assumed by the cork layers formed by the cork cambium, arising from the pericycle. The secondary phloëm will be in the form of a ring,

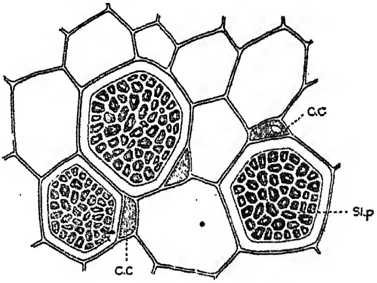


FIG. 58. Sieve-tube, transverse section (*Cucurbita maxima* stem.) C.C, companion cell; *Si.p*, sieve-plate. × 500.

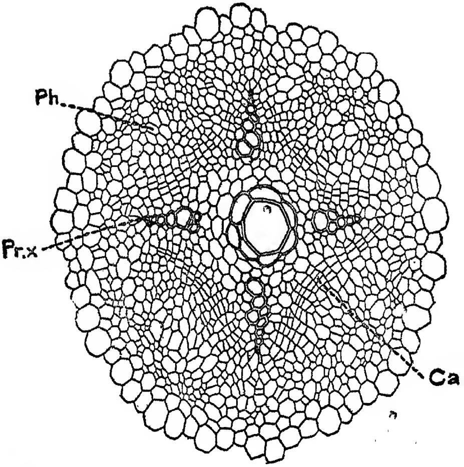


FIG. 59. Transverse section of the root of *Benincasa cerifera*. *Ca*, cambium; *Pr. x*, protoxylem; *Ph*, phloëm. × 200.

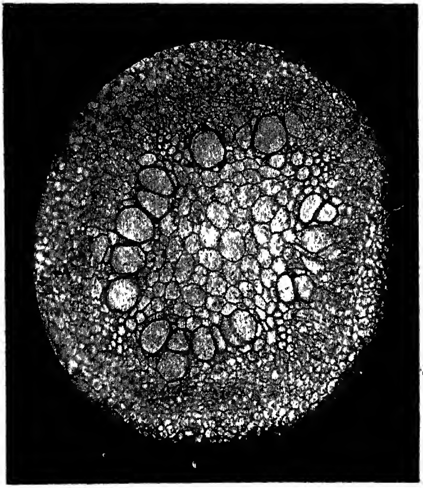


FIG. 60. Transverse section of the root of *Arachis hypogaea*. Note the four groups of protoxylem, the four groups of secondary xylem and the cambium. × 250.

although often interrupted by continuous layers of uniform cells called **medullary rays.** The masses of primary phloëm generally get pressed out of shape.

In all essential respects, the roots of dicotyledonous plants resemble the Cicer root so far as structure is concerned. The roots of *Sesbania grandiflora*, *Arachis hypogæa*. *Albizzia Lebbek* and *Benincasa cerifera* are similar to the Cicer root in having four protoxylem groups.

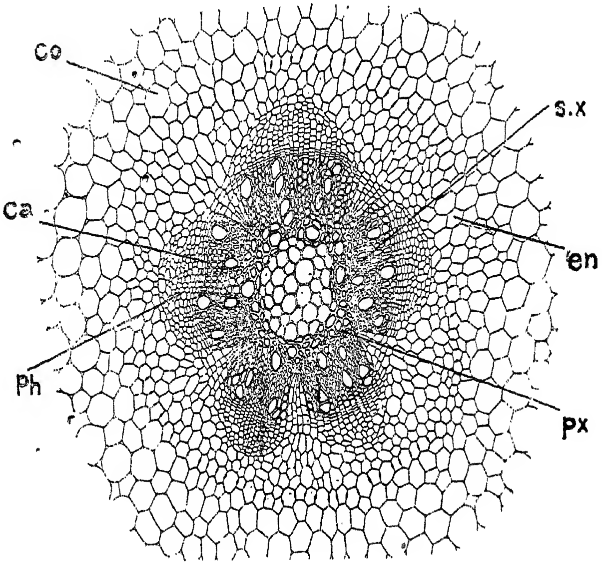


FIG. 61. Transverse section of the root of Castor to show the protoxylem and secondary xylem. *Ca*, Cambium; *Co*, cortex; *en*, endodermis; *Ph*, phloëm; *P.x*, primary xylem; *s.x*, secondary xylem. × 100.

However, in the matter of protoxylem groups, dicotyledonous roots vary. Instead of four groups, there may be two, three, six or more. But the number of xylem groups is never very large. The root of *Cucurbita maxima* and the aerial root of the Banyan have six protoxylem groups; in the root of the Radish and Mustard plants we find only two of

these. In the root of the Castor plant there are four, five or six protoxylem groups.

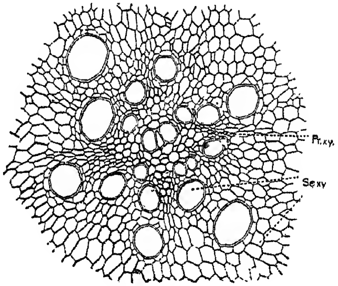


FIG. 62. Transverse section of an old root of *Albizzia Lebbek*. *Pr. xy*, primary xylem; *Se. xy*, secondary xylem. × 100.

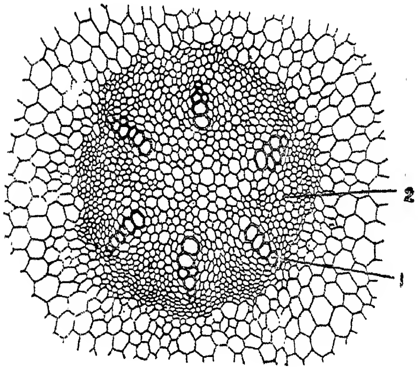


FIG. 63. Transverse section of a very young root of a Cucurbita. 1, protoxylem: 2, protophloëm. × 100.

After the formation of the cambium ring the secondary wood is formed, and after a time both become quite continuous; so that in an old root the protoxylem (i.e., the primary xylem) cannot be made out except in the earlier stages or in exceptional cases.

Structure of monocotyledonous roots.—Monocotyledonous roots do not differ from the dicotyledonous roots, so

far as the structure of the growing point is concerned. But in the absorbing and the conducting regions, there are some differences in structure. As an example of a monocotyledonous root we may examine the root of *Colocasia Antiquorum*. If we examine a transverse section of this root we find the stele and the cortex very well differentiated, as the endodermis is very distinct. Within the stele there are a number (varying from nine to eleven) of protoxylem groups alternating with as many phloëm masses. The pericycle is also very clearly seen. The cells of the endodermis have their lateral walls (and sometimes even their inner walls) thickened. All monocotyledonous roots have more or less the same structure.

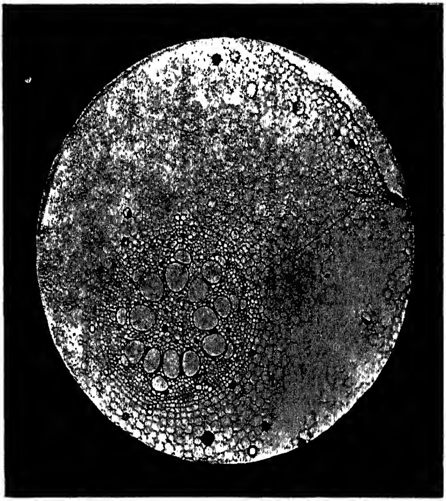


FIG. 64. Transverse section of the root of Colocasia showing the stele and the cortex. Note the nine protoxylem groups. × 75.

Within the stele, only the xylem and the phloëm groups are formed, and no cambium arises, as in the case of the dicotyledonous root. The development of protoxylem is centripetal. The cortex persists in the case of the monocotyledonous type of root, and some of the peripheral layers may also become thickened. This part is termed

exodermis, and it may consist of only a single layer of cells, as in the root of Paddy or, it may have more than one, as in the case of the Cholam root.

Structure of the roots of Musa, Andropogon and Allium.—As further examples of the monocotyledonous roots we may examine those of the Onion, *Andropogon Sorghum* and *Musa paradisiaca.*

In the Musa root the endodermis is a very striking layer, on account of the great thickening of the inner wall of its

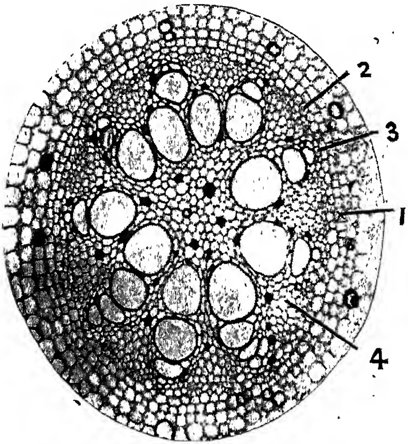


FIG. 65. Transverse section of Colocasia root showing the stele and the endodermis. 1, endodermis; 2, pericycle; 3, protoxylem 4, phloëm. × 150.

cells. Close to this is seen the pericycle, and the stele is somewhat different in structure from that in the Colocasia root. There are more than thirty groups of protoxylem alternating with as many phloëm groups. The central portion of the stele is occupied by numerous xylem vessels, and there are also phloëm groups irregularly disposed amidst the xylem. The cortex presents no special features, except the very regular arrangement of the cells with uniform intercellular spaces. Another marked feature is the lignification of the walls of all the cells within the stele except

the elements of the phloëm. The exodermis is not so well developed in this root.

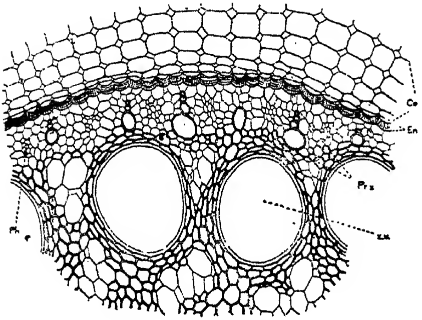


FIG. 66. Transverse section of Musa root showing a portion of the peripheral part of the stele. *Co*, cortex; *En*, endodermis; *Pr. x*, primary xylem; *x.v*, xylem vessel; *Ph*, phloëm. × 120.

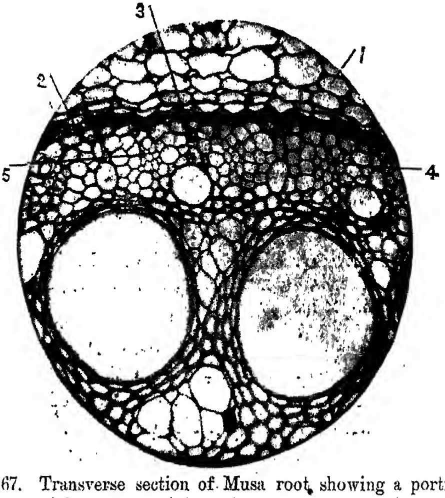


FIG. 67. Transverse section of Musa root, showing a portion of the peripheral part of the stele. 1, cortex; 2, endodermis; 3 pericycle; 4, phloëm; 5, xylem. × 150.

The root of the Onion plant presents a much simpler structure. The cortex is generally very broad and the stele

is comparatively very small. Within the stele there are only five to seven protoxylem groups. The endodermis is well seen on account of the thickening of the lateral and the inner walls of its cells. Below this layer is seen another layer, which is the pericycle.

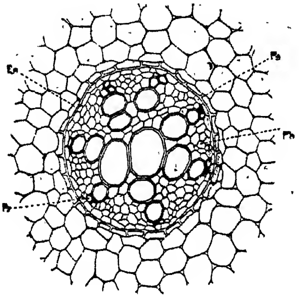


FIG. 68. Transverse section of a root of the Onion plant. *En*, endodermis; *Pe.*, pericycle; *Px*, protoxylem; *Ph*, phloëm. × 200.

The root of the Cholam plant though of the monocotyledonous type differs from the Colocasia and Musa roots in

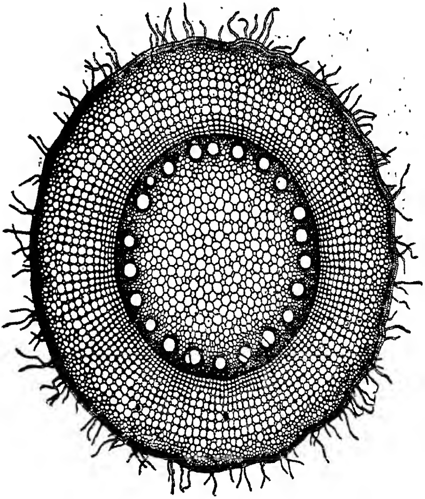


FIG. 69. Transverse section of a root of *Andropogon Sorghum*. × 25.

certain respects. Below the piliferous layer we see in this root a few layers of cells with very thick walls, and this is the **exodermis**. (See fig. 70.) In roots that are aerial the exodermis is very well developed, and the reason for this will become obvious after the study of the structure of the stem. The endodermis is similar to that of the Musa root. There are very many protoxylem groups, the number being sometimes over forty. Generally the pith consists of uniform cells. The pericycle is very well defined and lies immediately beneath the endodermis.

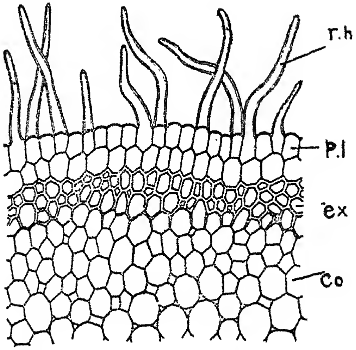


FIG. 70. Transverse view of a portion of the cortex of Cholam root. *r.h*, root-hair; *p.l*, piliferous layer; *ex*, exodermis; *co*, cortex. × 150.

In the case of roots the pericycle is a very important layer, because, in both dicotyledons and monocotyledons, the lateral roots arise from it just close to the protoxylem. In dicotyledonous roots, there will be as many longitudinal rows of lateral roots as there are protoxylem groups. For instance, we see in the tap-root of the Dolichos seedling four longitudinal rows of lateral roots, and the protoxylem groups are usually four in this root. The root of the Radish has only two protoxylem groups, and hence we see in it only two longitudinal rows of lateral roots.

Adaptation of structure to function in roots.—Having now learnt the structure of roots, we shall next study how far the structure is adapted for the function the roots have to

perform. Considering the absorptive work of the roots, it is obvious that roots should grow in length, otherwise the roots may not get water to absorb. The part of the root that is best adapted for this growth is certainly the free tip or end of the root. Other parts, the root-hair bearing region and the conducting regions are most unsuited to bring about the

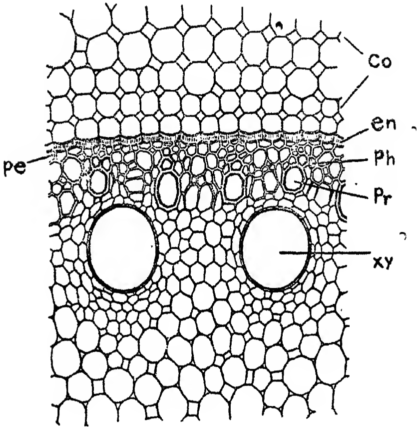


Fig. 71. Transverse view of a portion of the stele of Cholam root. *co*, cortex ; *en*, endodermis; *ph*, phloëm ; *pr*, primary xylem *xy*, xylem vessel ; *pe*, pericycle. × 150.

growth in length. Should these parts grow the root-hairs will be damaged very much. The naked tips are very delicate and need protection, and this is afforded by the root-caps. As the root-cap wears out at the outside, fresh layers are added on from the inside.

The growing tip is responsive to its surroundings and so when it meets with any obstruction, it turns aside and passes along the course of least resistance. The main work of the root-tip is to produce more cells and thus bring about elongation. There are really two portions in the root-tip, the extreme end or the formative region where the cells are always actively dividing and the elongating region in which the cells become gradually elongated.

While the young root-tips are finding their way and moving onwards by elongation amongst the soil particles, root-hairs appear on them, always a short distance back of the tip and keeping pace with it, as it advances in growth, and gradually dying off on the older portions. Thus the root-hairs are continually brought into the new parts of soil, where fresh supplies of the material are to be obtained. Root-hairs do not appear in the two regions of the growing tip. If they appear it is a sure indication that growth in length has practically ceased. As already pointed out, if the root-hairs were to appear in the part undergoing elongation, they are sure to be crushed and their efficiency would be impaired.

The root-tips elongate and pierce the soil with considerable force. The older parts of the roots are firmly fixed to the soil by their branches and root-hairs. The free tip moves onwards both by addition of new cells and the elongation of already existing cells. Division of cells is confined to the very apex of the root-tip, while the elongation is confined to a very short region and lies very close to the free apex. Thus it will be seen that the movement of the free apex and the direction of the application of the force are in the same straight line. Evidently this arrangement is a mechanical advantage. In driving a nail into a wall we find that a short one is driven in with ease whereas a long one cannot be driven straight and very often becomes bent.

The second region of the root is the absorbing region. Here the root-hairs are well developed from the outermost layer of the cortex. The cells of the cortex, lying below the piliferous layer become larger, and this is what is best for the storage of water. As the absorption increases, the pressure in the cells of the cortex will also increase. But this increase of pressure is not allowed to go on indefinitely. The conducting tissue draws away water from the cortex and this leads to the diminution of pressure. As root-hairs are developed all round the root, water must of necessity be stored in the cortex. Simultaneously with the development of root-hairs outside, vessels make their appearance in the stele. The xylem tissue (or the vessels) in the stele conducts

the water very quickly and thus the pressure in the cortex is very soon lessened.

The life of the root-hairs is generally very short. They are active from a few days to two or three weeks. We already know that these are the organs directly concerned in the absorption of water. The very small quantities of water existing in the form of films around the soil particles find their way into the interior of the root-hairs. The protoplasm within the root-hair seems to secrete certain substances that have a great affinity for water, and so the water gets into the root-hair. The root-hairs tend to increase the surface for absorption very considerably.

The older portions of the root are purely conducting regions. The root-hairs are in such parts decayed and the cells of the cortex become dead. In the dicotyledonous roots the cortex, as has already been said, sloughs off and the necessary protection is given by the cork layers derived from the pericycle. In monocotyledonous roots on the other hand, the cortex persists, though the cells cease to be living. The cortex is needed to afford protection to the structures inside.

Modifications in roots.—The root of a large tree must be extensive and capable of increasing in thickness. A large tree possesses a very stout trunk which may bear several very stout branches; and then the trunk needs propping up on all sides. Many of the roots at the base of the trunk become very much developed and look like so many buttresses to support the trunk. Often trees happen to grow in odd out-of-the-way places and even then the root-system adapts itself very well. For instance, a tree whose photograph is reproduced in fig. 72 was growing on a fort wall and the roots had to adapt themselves to their new situation and they have done it admirably, as may be seen in the figure.

So far we have been dealing only with normal roots of land plants. And the functions of these are only fixation and absorption of water. Roots have sometimes to perform other duties besides these. In the case of plants such as Sweet Potato, Radish, Carrot and Turnips the roots are at

first normal and they do the usual duty when they are young

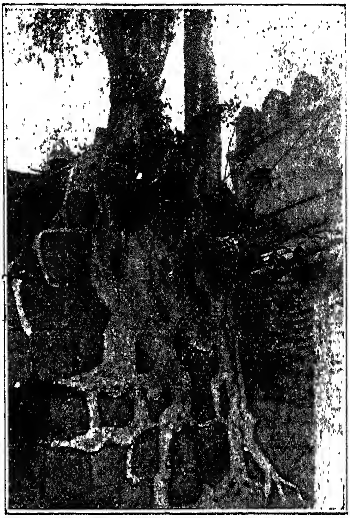


FIG. 72. A Peepul tree with its roots on the face of a fort wall.

But, as soon as they grow bigger, the roots begin to swell

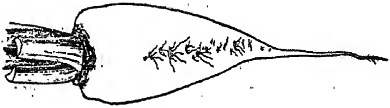


FIG. 73. Radish.

and increase in size. This is because the roots become the reservoirs for the storage of reserve material.

All normal roots are underground. There are, however, many plants in which they are not underground. For instance, in Pandanus, Banyan and Cholam plants there are roots that remain in the air for a long time, although they also penetrate into the soil afterwards. Such roots prop up the plants after entering the ground. When once they get into the soil, these roots also behave like ordinary roots.

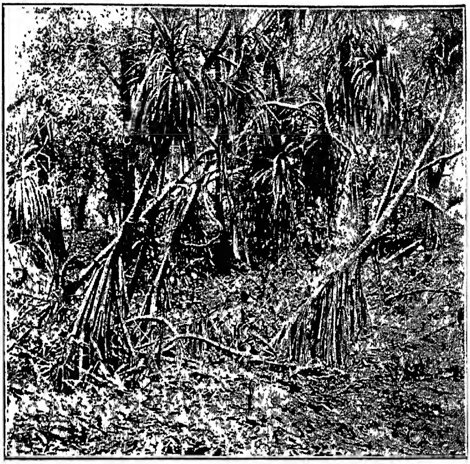


FIG. 74. The aerial roots of Pandanus.

The Banyan tree is an interesting one in many ways. Besides having the well-known aerial roots, it is sometimes

FIG. 75. The aerial roots of the Banyan tree

epiphytic in the seedling stage, especially when the seeds fall on other trees. We often see Banyan seedlings on Palmyra trunks. They grow in this position, and the roots encircling the stem and then gradually going downward get into the soil.

In some climbers such as the Pepper and *Pothos scandens* we find aerial roots at the nodes and these help the stem to cling on to the bark of the trees on which these grow. (See fig. 77.)

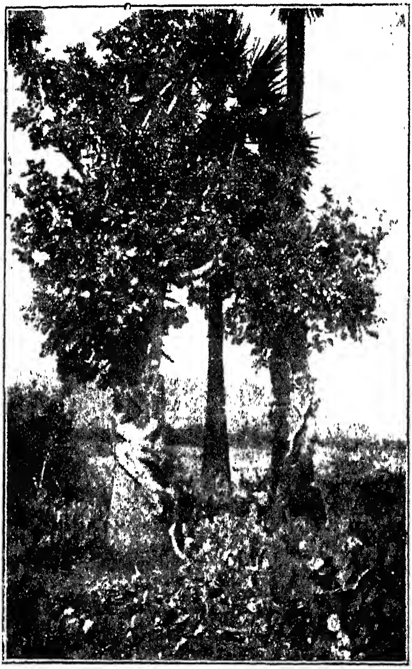


FIG. 76. A Banyan tree growing on the trunk of a Palmyra.

We have a large number of plants mostly of the family Orchideæ whose roots remain in the air without ever getting into the soil. All such plants are called **epiphytes**. The roots of epiphytes are specially adapted to obtain water and salts mostly from the atmosphere. The aerial roots of these plants have a few of the peripheral layers of the cortex modified

into a kind of spongy tissue, called the **velamen**, so as to enable the root to get water from the air. The orchid *Vanda Roxburghii* (see fig. 78) is a good example of an epiphyte.

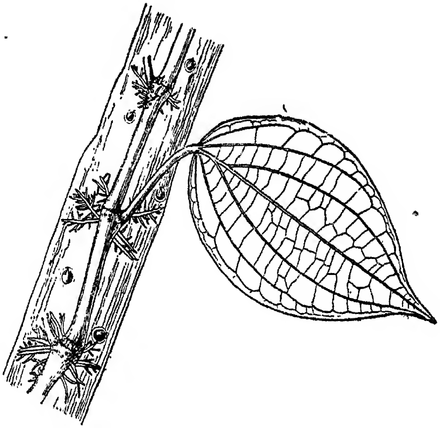


FIG. 77. Aerial roots of Pepper vine.

FIG. 78. *Vanda Roxburghii* (an epiphytic orchid).

The root-systems of the family Leguminosæ are specially interesting. In all plants of this order the roots develop

special bodies varying in shape and size, and these are called **bacterial nodules**. They are called so, because they are brought into existence by bacteria. These nodules have the power of using the nitrogen of the atmosphere and thus lead to an increase of nitrogen in the soil.

FIG. 79. The breathing roots or pneumatophores of Avicennia.

Plants growing in salt marshes have their roots in the mire. So the root-system cannot obtain sufficient quantities of oxygen for respiration unless there is some special adaptation. The roots of these plants send up into the air special roots possessing a hole at the top to allow air to get into the

root-system. These are called breathing roots or **pneumatophores** or **pneumathodes.**

Lastly we should mention the modified roots of parasitic plants, such as the Loranthus and the Viscums. These parasitic plants grow on the branches of other plants, sending their modified roots **(haustoria)** into the interior of the branches of their host plants. Complete fusion takes place between the xylem of the haustoria and that of the host plant. Some parasitic plants attach themselves to the roots of their host plants, instead of the stem or branches. *Striga lutea* and the Sandal wood tree are well-known parasites. Both these plants do not look like parasites, because the haustoria are attached to the roots of the host plants that are underground.

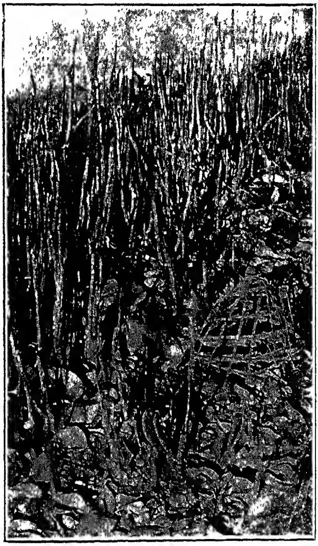


FIG. 80. The breathing roots of Avicennia.

A very remarkable root parasite thrives in the island of Sumatra. It consists of only a gigantic flower attached to the root of vines. When in full bloom the flower is said to be about a metre in diameter and many pounds in weight.

CHAPTER V

THE SHOOT

FROM the study of seeds and seedlings we have learnt that the embryo plant consists of a primary axis and cotyledons and that the former grows into a seedling. The primary axis invariably emerges out of the soil, at first as a loop, and then erecting itself grows and produces green leaves. Further the plumule, which in the seedling develops into an axis bearing green leaves, will always go straight up seeking air and light. We speak of the aerial portion of a plant as the **shoot** and in the case of a seedling the shoot consists of only a few leaves and an axis.

The shoot-system.—By closely looking at the branches and twigs of any common tree we find that these grow out into the air, so as to get plenty of air and sufficient light. The parts of the shoot-system need air and light to discharge their functions and, therefore, stems and branches grow towards the light. All green plants possess the power of adjusting their branches to light. That the shoot of a young plant has a perception of the direction may easily be demonstrated. If a flower-pot in which seedlings are growing be placed on its side, so as to have the axis of the seedling parallel to the ground, the shoot will begin to curve upward somewhere near the young tip, and in about an hour or two there will be a distinct curvature and the shoot will assume an erect posture by bending at right angles to the ground. The upright position of the stem is after all the most advantageous one for the plant and so the shoots of all green plants assume this position.

The plumule, which develops into the primary shoot in a seedling, is only a bud occupying the free end of the primary axis. We cannot make out its structure at the earlier stages of its development. But, as soon as it begins to grow in length, it becomes apparent that it is only a short stem hidden by a number of enfolding leaves. Gradually the stem elongates, the nodes become separated from one another and the leaves also, which are crowded upon it at first, become separated. The leaves develop in acropetal succession.

All plants begin their lives with a single stem and afterwards branches grow out from the axils of leaves. Branches behave like the main stem, in the matter of producing branches. So the shoot-system of a plant or a tree is merely a repetition of the stem from which it arises, and it consists of a number of branches, and every one of them consists of an axis, and the leaves and flowers borne by it. The axis is divisible into nodes and internodes, and it terminates in a bud. All growing normal branches have buds, at their free ends. If the apex of a branch ceases to be active, on account of unfavourable conditions, the terminal bud assumes the form of a resting bud and becomes prominent as in Mango, Cinnamomum, Rhododendron and Mahogany.

In addition to the terminal bud, every branch possesses also axillary buds. In a branch all the leaves have axillary buds, and so there will be as many buds on it as there are leaves. Generally these buds do not arise from the axils of cotyledons, but even this is not without an exception. Buds develop from the axils of the cotyledons in the Ground-nut plant *(Arachis hypogæa)* and in *Cicer arietinum*.

When the plumule is injured while still very young axillary buds sometimes grow out from the axils of the cotyledons as in the case of the Mango and a few leguminous seeds *(Canavalia ensiformis)*.

Although buds normally arise from the axils of leaves and from the tips of branches there are instances of buds forming on callus when stems are cut and also on leaves. (See fig. 333). Such buds are called **adventitious buds.** From old parts of stems very often branches arise and these are from buds lying buried deep in the stem. These are known as dormant buds. Resting buds such as those of Rhododendron with prominent scale-leaves are called scaly buds. (See fig. 84.)

The primary shoot, in virtue of its having axillary buds, is capable of producing a large number of twigs. So the young branches increase rapidly causing the formation of a large shoot-system, which constitutes the body of a shrub or the head of a tree. The branching and the general shape of the head of a tree is sometimes quite characteristic of the species

Fig. 81. Viscum on the branches of Hardwickia.

Fig. 82. Striga on the roots of *Lepidagathis cristata*. *a*, *b* and *c* are the parasitic Striga plants.

FIG. 83. Loranthus on a branch of *Albizzia amara.*

CHAPTER V

THE SHOOT

FROM the study of seeds and seedlings we have learnt that the embryo plant consists of a primary axis and cotyledons and that the former grows into a seedling. The primary axis invariably emerges out of the soil, at first as a loop, and then erecting itself grows and produces green leaves. Further the plumule, which in the seedling develops into an axis bearing green leaves, will always go straight up seeking air and light. We speak of the aerial portion of a plant as the **shoot** and in the case of a seedling the shoot consists of only a few leaves and an axis.

The shoot-system.—By closely looking at the branches and twigs of any common tree we find that these grow out into the air, so as to get plenty of air and sufficient light. The parts of the shoot-system need air and light to discharge their functions and, therefore, stems and branches grow towards the light. All green plants possess the power of adjusting their branches to light. That the shoot of a young plant has a perception of the direction may easily be demonstrated. If a flower-pot in which seedlings are growing be placed on its side, so as to have the axis of the seedling parallel to the ground, the shoot will begin to curve upward somewhere near the young tip, and in about an hour or two there will be a distinct curvature and the shoot will assume an erect posture by bending at right angles to the ground. The upright position of the stem is after all the most advantageous one for the plant and so the shoots of all green plants assume this position.

The plumule, which develops into the primary shoot in a seedling, is only a bud occupying the free end of the primary axis. We cannot make out its structure at the earlier stages of its development. But, as soon as it begins to grow in length, it becomes apparent that it is only a short stem hidden by a number of enfolding leaves. Gradually the stem elongates, the nodes become separated from one another and the leaves also, which are crowded upon it at first, become separated. The leaves develop in acropetal succession.

All plants begin their lives with a single stem and afterwards branches grow out from the axils of leaves. Branches behave like the main stem, in the matter of producing branches. So the shoot-system of a plant or a tree is merely a repetition of the stem from which it arises, and it consists of a number of branches, and every one of them consists of an axis, and the leaves and flowers borne by it. The axis is divisible into nodes and internodes, and it terminates in a bud. All growing normal branches have buds, at their free ends. If the apex of a branch ceases to be active, on account of unfavourable conditions, the terminal bud assumes the form of a resting bud and becomes prominent as in Mango, Cinnamomum, Rhododendron and Mahogany.

In addition to the terminal bud, every branch possesses also axillary buds. In a branch all the leaves have axillary buds, and so there will be as many buds on it as there are leaves. Generally these buds do not arise from the axils of cotyledons, but even this is not without an exception. Buds develop from the axils of the cotyledons in the Ground-nut plant *(Arachis hypogæa)* and in *Cicer arietinum*.

When the plumule is injured while still very young axillary buds sometimes grow out from the axils of the cotyledons as in the case of the Mango and a few leguminous seeds *(Canavalia ensiformis)*.

Although buds normally arise from the axils of leaves and from the tips of branches there are instances of buds forming on callus when stems are cut and also on leaves. (See fig. 333). Such buds are called **adventitious buds.** From old parts of stems very often branches arise and these are from buds lying buried deep in the stem. These are known as dormant buds. Resting buds such as those of Rhododendron with prominent scale-leaves are called scaly buds. (See fig. 84.)

The primary shoot, in virtue of its having axillary buds, is capable of producing a large number of twigs. So the young branches increase rapidly causing the formation of a large shoot-system, which constitutes the body of a shrub or the head of a tree. The branching and the general shape of the head of a tree is sometimes quite characteristic of the species

as in *Odina Wodier*, *Ailanthus excelsa*, *Acacia planifrons* and the Rain Tree.

FIG. 84. Scaly buds of Rhododendron.

The bud and the branch.—A bud, terminal or axillary, is only an undeveloped branch. It consists of a free end which is a mass of meristem cells, covered by the very tender

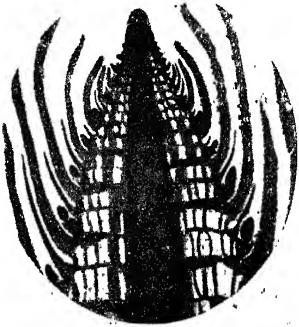


FIG. 85. A longitudinal section of the stem of Hippuris through the growing point. × 40. (From a slide prepared by Dr. M. A. Sampathkumaran of Bangalore.)

young leaves in the course of development. The leaves arising as protuberances from the surface of the free end, which is called the growing point, grow earlier and faster than the axis so that it may have protection. (See figs. 85

and 86.) A branch may have a large number of buds, but only those that have the best chance grow. There are

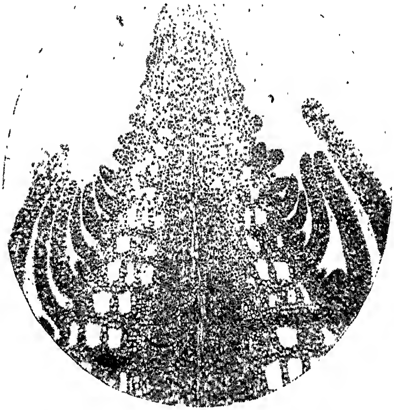


FIG. 86. A longitudinal section of the stem of Hippuris through the growing point. × 80. (From a slide prepared by Dr. M. A. Sampathkumaran of Bangalore.)

FIG. 87. A longitudinal section of the stem of Elodea through the growing point. × 40. (From a slide prepared by Dr. W. Dudgeon of Allahabad.)

generally more buds than there is space for, and so there will be a struggle for existence amongst them. Those buds that have more sunlight and room than the others grow best. The terminal bud and the axillary buds towards the top of the branch grow better and become larger because they get more sunlight, air and room.

Twigs in some cases tell the story of their own growth. By an examination of a twig it is possible, in many cases, to

FIG. 88. A longitudinal section of the stem of Elodea through the growing point. × 80. (From a slide prepared by Dr. W. Dudgeon of Allahabad.)

determine exactly its age. It is especially easy in twigs that possess scaly leaves covering the bud, to determine their age. In such twigs, the scars of the scaly leaves are succeeded by those of the foliage leaves. The twigs of Mango and Mahogany are good examples to illustrate this point.

The primary shoot of a plant is at first single. It may continue to grow and produce branches, or it may grow as a simple straight stem without any branches and remain so throughout its life. In the case of several palms, such as the Coconut, Areca-nut, Palmyra and other palms, the stem is

single, and it bears no axillary buds. When a stem goes on elongating by the growth of its terminal bud for a long time it is said to be a branch with indefinite growth. Sooner or

FIG. 89. Twig of Mahogany. *a*, scales; *b*, *c*, *d*, scale scars

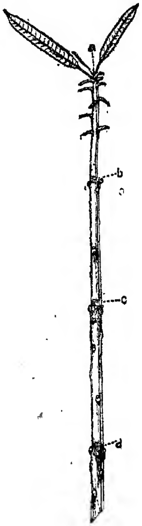


FIG. 90. Twig of Mango. *a*, terminal scaly bud. *b*, *c*, *d*, scale scars.

later, branches grow out from the lower axils also and these may be numerous and all smaller than the main stem. This mode of branching of the stem is called **racemose**, and the branch whose elongation is due to the growth of the terminal bud is said to be a **monopodial** branch.

The terminal bud, instead of continuing the growth of the axis, very often ends in spines or flowers and so the main axis ceases to elongate. For instance, in the plant *Carissa Carandas*, the growing point ends in two spines and the two axillary buds in the axils of the leaves immediately below the spines grow into branches. These also, after

producing two or three pairs of leaves, end in spines and behave in the same manner.

In the Cotton plant the flowers are opposite the leaves. This is so as the main axis ends in a flower and there is no growing point to continue the growth of the same axis. The axillary bud lying immediately below the terminal growing point grows and continues the axis, by pushing aside the flower. So the internodes of the flower bearing branch in the Cotton plant are not all derived from the same growing point. Such branches as these are called **sympodial** branches and the branching is **cymose**.

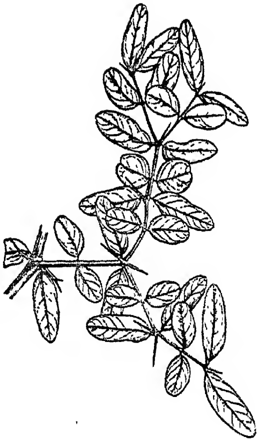


FIG. 91. A branch of *Carissa Carandas*.

Branches of *Cissus quadrangularis* bearing **tendrils** (climbing organs) may be taken as an example of a sympodial stem. Obtain some branches of this plant and choose two, one having tendrils from every node and another having them only at some of the nodes. In a branch having tendrils from every node an internode springs from between a leaf and a tendril. On the other hand in a branch without tendrils at the nodes, we find a leaf, an axillary bud and the main axis, at every node. The axillary bud is small and it lies between the leaf and the main axis. By comparing the tendril bearing node with one

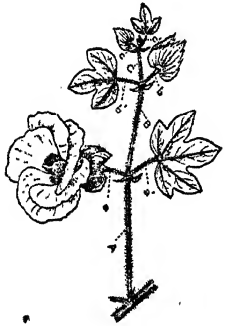


FIG. 92. A flower bearing branch of the cotton plant. A, B, C, internodes; *a*, *b*, *c*, flowers; *a'*, *b'*, *c'*, leaves.

having no tendrils, it is possible to make out the nature of the tendril. The tendril is found opposite the leaf and the internode lies between it and the leaf. Judging from the relative position of parts, the tendril is in the position of the main axis, and the internode is found in the place of the axillary bud. In the Cissus branch figured here the internode "B" arising from the axil of the first leaf is evidently derived from the axillary bud of that leaf. The tendril found opposite to this leaf is really the main axis which has given rise to the axillary bud, now grown into an internode "B," the second leaf and the second tendril. As the axillary bud has grown more vigorously than the main axis (now a tendril) it has pushed it aside. The internode "C," the third tendril and the third leaf are derived from the axillary bud of the second leaf. Similarly the internodes "D" and "E" are derived from two different axillary buds. The axis of the branch is straight and consists of the several internodes "A," "B," "C" and "D." Now it is obvious that all these internodes though continuous are not produced by the same growing point, and that each one is developed from a separate growing point. The internode "A" has an origin different from that of "B" or "C" or "D." The whole branch "A" to "D" though appearing as one continuous piece of axis really consists of four separate axes derived from different growing points.

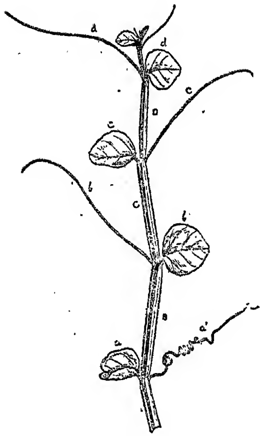


FIG. 93. A tendril bearing branch of *Cissus quadrangularis*. A, B, C, D, internodes; *a*, *b*, *c*, *d*, leaves; *a′*, *b′*, *c′*, *d′*, tendrils.

Modified stems.—Stems generally grow erect, but they do not always do so. Many plants have very weak stems and they cannot be expected to maintain an erect posture

without supports. Such plants if not supported must grow along the surface of the soil. The branches of the plants *Centella asiatica*, *Ipomœa reniformis* and *Lippia nodiflora* creep along the ground ; and as they do so, from their nodes adventitious roots arise by which they get fixed to the soil. The axillary buds at the nodes grow erect producing leaves and branches. These are capable of becoming independent plants, if they get severed. Such branches as these are called **runners** or **stolons.**

G. 94. Stolons of *Centella asiatica.*

Certain plants have a tendency, because of their weak stems, to twine themselves round a support. Several species of Ipomœa, *Dolichos Lablab*, *Clitoria Ternatea* and *Teramnus labialis* are such plants. All these plants are called **twiners**, because their stems twine round a support. The support may be the stalks and branches of plants growing near. When the stems of climbers become thick and massive, they are called **lianes.** For instance the plant *Combretum ovalifolium* is such a

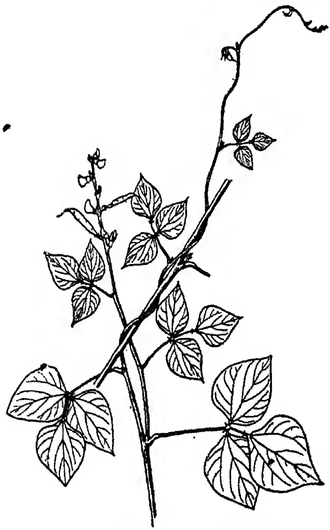


Fig. 95. Twining stem of *Dolichos Lablab.*

Again there are certain plants like the Gourds and the Cucumbers that climb by means of special structures called

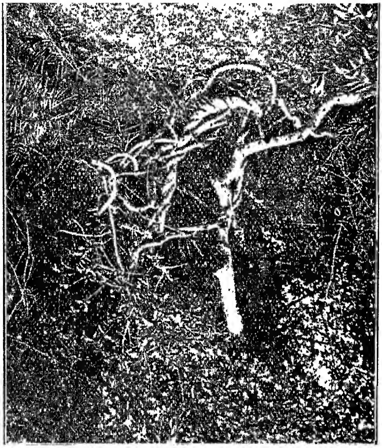


FIG. 96. Old twining stems of *Combretum ovalifolium*.

tendrils. The nature of the tendril varies with the kind of plant. It is a branch in Passiflora, because it springs from

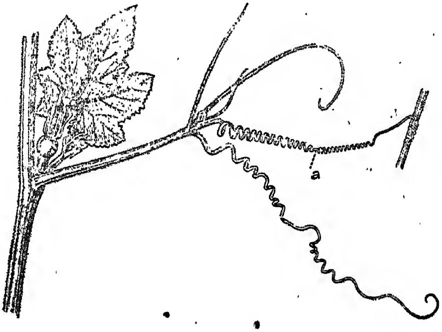


FIG. 97. Tendrils of Cucurbita.

the axil of a leaf; in the Pea plant the tendril is in the position of a leaflet; it may arise from the apex of a leaf,

as in *Gloriosa superba*; the flower-stalk sometimes develops into a tendril, as in Cardiospermum; in some species of Cucurbita it is a stem although it may appear to be a leaf.

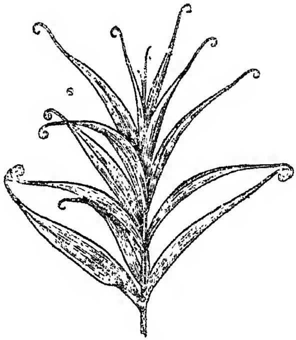


FIG. 98. Tendril bearing leaves of *Gloriosa superba*.

The axillary branches sometimes remain short and become pointed at the tips instead of developing into leafy branches; such branches are called **spines** or **thorns**. Very often these spines, or arrested branches bear leaves and may also develop into leafy branches under exceptionally favourable conditions, and especially under cultivation.

Underground stems.—There are plants in which the main portion of the leaf-bearing axis remains generally underground. The hariali grass, Curcuma, Plantain and Onion are familiar examples. Cyperus, *Convolvulus arvensis*, *Aristolochia bracteata* and many other weeds have perennial subterranean stems from which aerial branches arise year after year. Their persistency as weeds is due to this special feature.

When stems become subterranean they are ill-adapted for the display of leaves and flowers. Then they must produce either leaves and flowers with stalks long enough to push them above the ground or aerial branches capable of bearing leaves and flowers. Although the underground portion is a disadvantage in certain respects, it is an advantage in some other respects. Underground stems are less liable to injury by browsing animals and they are protected from drying up,

in addition to their being safe places for the storage of reserve food.

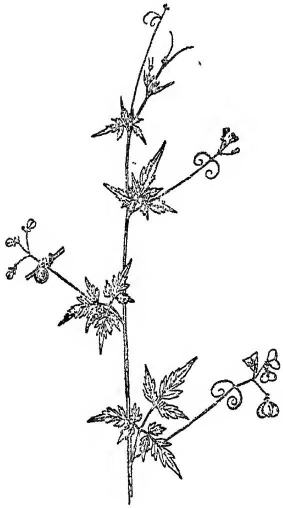


Fig. 99. Tendrils of Cardiospermum.

As underground stems differ considerably they are usually classified into different kinds. The underground branches in some plants hardly differ from the aerial ones, except in the loss of green colour and foliage leaves., Other plants show distinct modifications in their underground stems and they are classified as rhizomes or root-stocks, tubers, bulbs and corms.

The underground stems of *Canna indica, Curcuma longa* and *Panicum repens* grow horizontally giving off leafy shoots above and roots below. They become thick on account of the storage of reserve food, and elongate rather slowly. Such stems as these are called **rhizomes.** Sometimes they are also called **root-stocks** on account of their resemblance to roots. The nodes, internodes and axillary buds can be made out in rhizomes. Ordinarily they grow horizontally and do best at a certain definite depth in the soil. If this is changed they will go downward or grow upwards until the average depth is attained. This maintenance of the average level in the soil is probably advantageous, because greater depth is sure to interfere with the development of aerial shoots, while extreme shallowness would mean less protection.

Rhizomes grow and branch freely. In some plants as in turmeric, the whole of the shoot system may consist entirely of underground stems, or they may regularly bear aerial branches with foliage leaves and flowers as in the case of *Canna indica.* The rhizome may grow in length, the apical

bud persisting and axillary buds growing out into aerial branches, or the apical bud may grow out as an aerial branch, the growth of the rhizome in length being continued by lateral buds as in Musa and Canna. The former is of the monopodial type and the latter is sympodial.

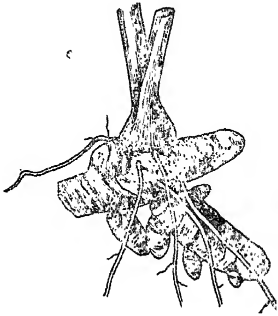


FIG. 100. Rhizome of Curcuma.

Plants having rhizomes are well adapted for invading and taking hold of the soil already occupied by other plants, because the rhizomes creep through the soil and occupy the places where seeds have absolutely no chance to spread.

In some rhizomes it is possible to make out the nodes, internodes and the axillary buds.

Sometimes we meet with plants in which a few branches remain underground, and these instead of elongating swell and become thick on account of the storage of starch. In such branches leaves do not develop but axillary buds are always present. Underground branches of this nature are known as **tubers.** The Potato is a good example of a tuber. In the Potato plant, in addition to the tubers, there are also ordinary branches with leaves.

In tubers and rhizomes the axis is well developed, but the leaves are either absent or they are reduced to scale-leaves.

There are some plants in which the axis remains small without development, but the leaves grow and become fleshy so as to serve as reservoirs for reserve food. This is exactly what happens in the case of the Onion plant. If we cut an Onion longitudinally, we find a disc-like structure

bearing roots below and a number of sheathing fleshy scale leaves and buds above. This disc is the stem or the axis very much condensed, and the whole structure is called a **bulb.** As further examples we may mention those of Crinum, Scilla, Urginea and Polianthes.

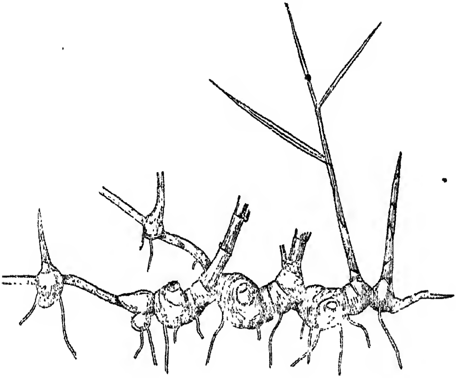


FIG. 101. Rhizome of *Panicum repens.*

The inner leaves of a bulb are either fleshy scales as in Onion or they are the enlarged sheathing leaf bases of ordinary leaves as in Crinum. The bulb in Polianthes is generally like that of Crinum or Onion, but the axis becomes a large mass instead of remaining small and the scale leaves (leaf bases) are very few. Externally it is like a bulb and so such ones are sometimes called "**solid bulbs.**" This is really an intermediate form of stem leading to what is usually described as a **corm.**

There are a few plants in which the axis, lying at or below the level of the soil, swells out into a spherical shape on account of the accumulation of food material. The leaves either become reduced or they are entirely absent. The underground massive part of the plant Amorphophallus, or Synantherias is the main stem modified and this is a good example of a naked corm. Though this is essentially like a tuber, it differs from it in being a main stem instead of a branch. Hence it is called a **corm.** The so-called "solid bulbs" are corms covered by scale-leaves.

The corm of Amorphophallus bears a large bud at its depressed apex. The apical bud pushes out the leaves one at

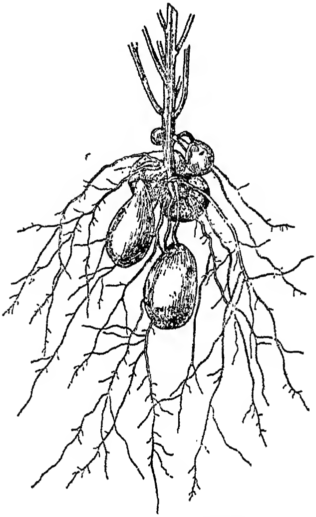


FIG. 102. Tubers of the Potato plant.

a time. In addition to this bud a number of smaller ones are found scattered all over the surface of the corm and also

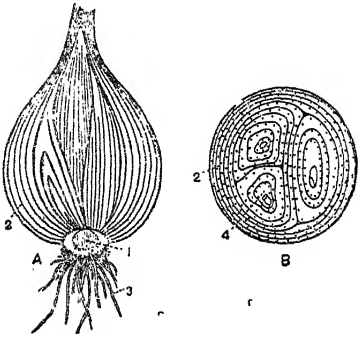


FIG. 103. Bulb of an Onion plant. A, longitudinal and B, transverse sections. 1, axis; 2, scale-leaves; 3, roots; 4, axillary buds.

in the depressed part. Some of these may develop into daughter-corms. Sometimes we find corms of different periods of growth remaining attached to one another. For instance the corms in a wild species, *Synantherias sylvatica*, consist usually of two bodies as shown in fig. 104. The upper one is the corm of the plant that has resulted during the period of growth in 1914, and the lower one is of the year 1913. From the corms sometimes buds grow out and become elongated somewhat like the rhizome. The underground structure found in *Colocasia Antiquorum*, in continuation with the developing bud, is a corm; and this usually bears branches somewhat elongated and resembling a rhizome.

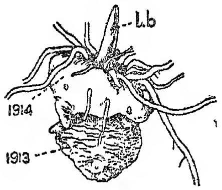


FIG. 104. Corm of *Synantherias sylvatica*, Schott. *l b*, leaf bud.

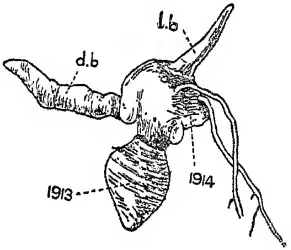


FIG. 105. Corm of *Synantherias sylvatica*. *l.b*, leaf bud; *d.b*, daughter bud.

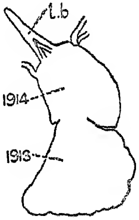


FIG. 106. Corm of *Synantherias sylvatica* cut longitudinally. *l.b*, leaf bud.

The internal structure of the stem.

The structure of the stem varies according to the species of the plant and the stage of development in the same plant. In plants having a short duration of life, as in the case of annuals, the stem is generally soft and herbaceous. In shrubs and trees the stem is herbaceous in the younger parts, and is woody and hard in older portions.

The structure of the growing point of the stem is the same in all plants, so far as the essential points are

concerned. It consists of a mass of meristematic cells terminating in a cone and covered by the developing young leaves. Axillary branches also arise very early as protuberances in the axils of leaves near the actual growing point. They remain dormant for a very long time. It is the leaf that grows rapidly one after the other while the axis does so very slowly. In consequence of this difference in growth between the axis and its appendages, the young leaves developing near the growing point cover and protect it.

Structure of Sunflower stem.—To learn the internal structure of the stem it is necessary to select the stems of a few plants as types and study them. We may begin the study with the stem of a Sunflower plant or of *Vernonia cinerea*. If we examine a transverse section of this stem taken an inch or two below the growing point we find in the central part a mass of thin-walled cells, and this portion of the stem is called the **pith** or **medulla.** All round the pith which occupies rather a large part of the area in the transverse section there are groups of cells with thick cell-walls arranged in the form of a ring.

These groups of cells disposed in the form of a ring around the medulla are called **fibro-vascular-bundles.** The portion of the stem lying just outside the ring of fibro-vascular bundles and forming the peripheral part of the stem is termed the **cortex.** It consists of a number of layers of parenchymatous cells bounded externally by a layer of cells called the **epidermis.** In young stems some of the layers of the cortex lying just below the epidermis consist of cells with their cell-walls thickened, especially at the corners.

These isolated groups standing out prominently, by reason of their thickened cell-walls, are the cut ends of the vascular bundles that run longitudinally in the stem, and they increase continually in thickness, especially in the case of the dicotyledonous stems. The mass of wood found in the stems of timber trees of several years' growth is nothing more than a mass of vascular bundles packed together closely. Between the vascular bundles there are bands of parenchymatous cells which are, though smaller, similar to those of the pith. These bands of parenchymatous cells seen in the transverse section between the vascular bundles, and running from the cortex to the medulla are called **medullary rays.** At first

when the vascular bundles are isolated these medullary rays are broad. Later on new vascular bundles arise in these rays making the bundles continuous.

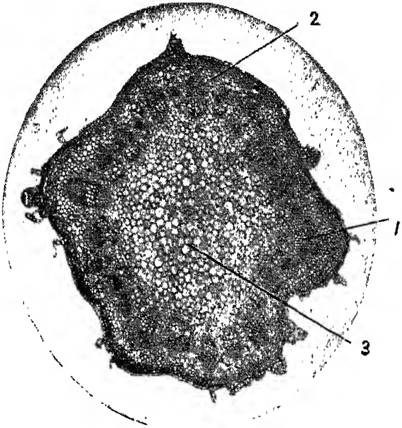


FIG. 107. Transverse section of a Sunflower stem. 1, vascular bundles; 2, cortex; 3, medulla or pith. × 25.

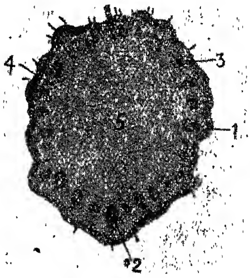


FIG. 108. Transverse section of a *Vernonia cinerea* stem. 1, epidermis; 2, vascular bundle; 3, cortex; 4, medullary ray; 5, pith. × 25.

The structure of a single vascular bundle of the Sunflower stem is shown in fig. 110. The larger cavities with thick walls are the vessels. Amidst the vessels, there are small cells with thick lignified walls. They are ordinary

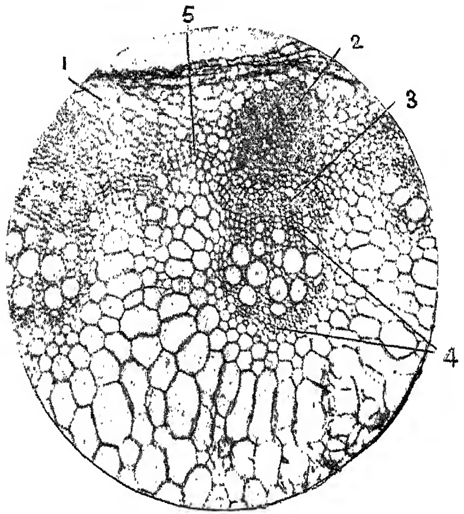


FIG. 109. Transverse section of a portion of the Sunflower stem. 1, cortex; 2, fibre bundle; 3, phloëm; 4, xylem; 5, cambium. × 150.

parenchymatous cells whose walls are lignified and fibres. The lignified vessels, wood parenchyma and fibres form a compact group near the pith, and it is the xylem of the vascular bundle. Besides these thick-walled elements, forming the xylem, there are other groups of cells with thin walls which are also the constituents of the bundle. We have, as a matter of fact, three distinct parts in a vascular bundle, viz., the **xylem**, the **cambium** and the **phloëm**.

The xylem consists of thick-walled vessels and cells and fibres. It lies close to the pith. Vessels lying close to the pith are the oldest ones and those on the opposite side far away from the pith are the youngest.

Next to the xylem towards the periphery of the stem we see several layers of thin-walled cells. Of these those that

are rectangular and regular remain close to the xylem, and this is the **cambium region.** All the cells of this region are not meristematic; only one layer is so, and it is the **cambium** proper. In the vasular bundle the most delicate part is the cambium.

The cambiums of the bundles found in the young stem do not touch each other laterally, because medullary rays run between the bundles. Later on these areas of cambium become united into a continuous ring. The cells of the medullary ray lying between the cambium of the bundles become active, change into meristem and connect the adjoining pieces of the cambium.

The tissues lying outside the cambium consist of thin-walled cells grouped together with a mass of very thick-walled cells, outside, towards the cortex. The thin-walled cells constitute the phloëm, and the mass of uniform cells with thick walls is a group of fibres. The phloëm is really made up of sieve tubes and parenchymatous cells and it is protected by a mass of fibres lying outside, towards the cortex. In the Sunflower stem we find fibres associated with the vascular bundles, and so the bundle is sometimes called a **fibro-vascular bundle.** The fibre bundle is not a part of the vascular bundle.

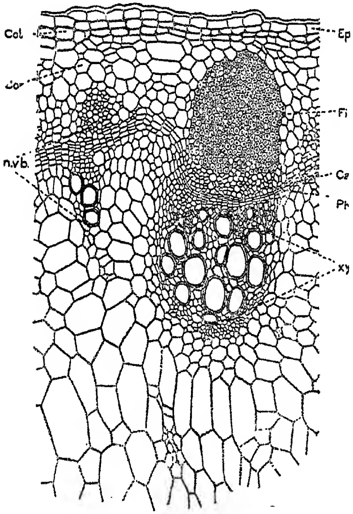


FIG. 110. Transverse section of a single vascular bundle of the Sunflower stem. *Ep*, epidermis; *Col*, collenchyma; *Fi*, fibre bundle; *Ph*, phloëm; *Ca*, cambium; *Xy*, xylem; n.v.b, new vascular bundle. × 150.

To understand the structure of the elements of the various parts of a vascular bundle, it is necessary to examine a median longitudinal section. Such a section is represented in fig. 113. The pith and the cortex consist of thin-walled parenchyma. The outermost layer of the stem consists of thin-walled flattened cells; this is the **epidermis.** The

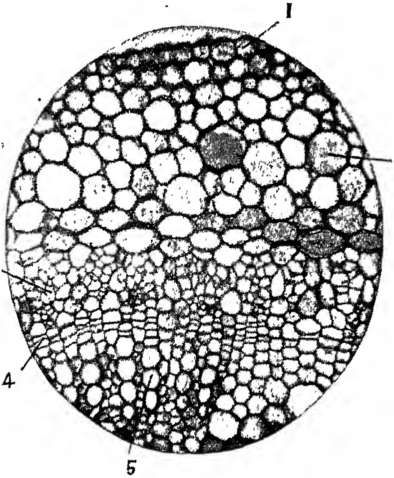


FIG. 111. Transverse section of a very young stem of *cannabinus.* 1, epidermis; 2, cortex; 3, phloëm; 4, cambium; 5, xylem. × 100.

outer free walls of the epidermal cells are thickened, and the thickened part is known as the **cuticle,** especially when the thickening is extensive and the thickened part can be peeled of as a separate membrane. Within the cortex the various elements of the vascular bundle and fibre are seen. The innermost layer of the cortex is in contact with the fibre bundle. The fibres have very thick walls and they are also pitted though slightly. Next to the fibres lie the sieve tubes and ordinary parenchymatous cells. The sieve tubes are all small and so they can be seen well only under high powers of the microscope. The phloëm is succeeded by the cambium layer and after this are seen the xylem elements, vessels, fibres and wood parenchyma cells. The vessels

towards the cambium are all pitted and near the pith lie the annular and spiral vessels.

We have already spoken about the importance of the cambium layer. It is really a single layer of cells and these cells are always undergoing division giving rise to new cells both towards the phloëm and the xylem. Cells near the xylem become gradually changed into xylem elements (pitted vessels, wood parenchyma and fibres), and those next to the phloëm become sieve tubes and parenchymatous cells.

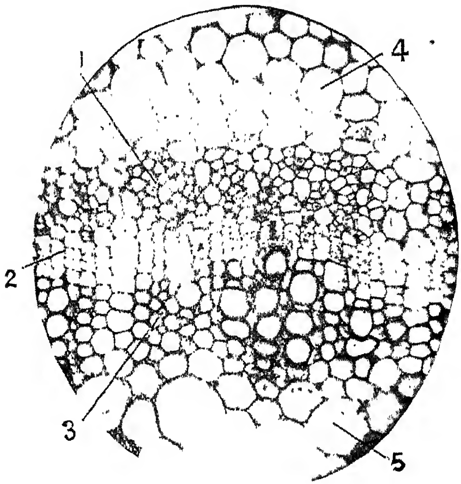


FIG. 112. Transverse section of a portion of a very young stem of *Hibiscus cannabinus*. 1, phloëm; 2, cambium; 3, xylem; 4, cortex; 5, medulla. × 200.

The cambium exists at first as small patches between the xylem and the phloëm of the isolated vascular bundles. The formation of the cambium ring is a gradual process. A little below the growing point, the uniform mass of cells becomes differentiated into a central core, in which the cells are elongated in the longitudinal direction and a peripheral portion wherein the cells are not so much elongated. The central core is called the **stele**. Here and there, within the

stele which is uniform in its structure, cells begin to divide rather rapidly, and as a result of this division a continuous ring of small cells is formed. The portion of the stele inside this ring is the medulla or the pith. In this ring which is called the **procambium** isolated strands appear (**procambial strands**). And these strands become changed gradually into vascular bundles, separated by medullary rays. The transformation of the procambial strand into the vascular bundle

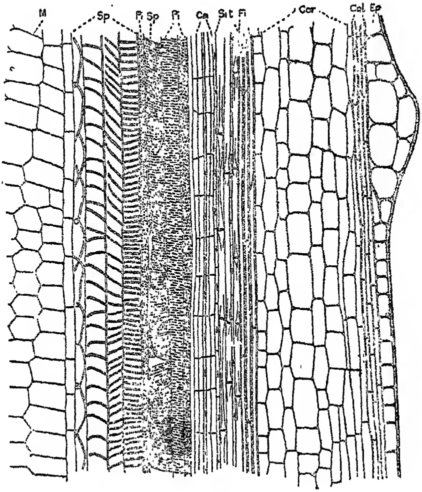


FIG. 113. Longitudinal section of the Sunflower stem. *Ep*, epidermis ; *Col*, collenchyma ; *Cor*, cortex ; *Fi*, fibre ; *Si*, sieve tube ; *Ca*, cambium ; *Pi*, pitted vessels ; *Sp*, spiral vessels ; *M*, medulla or pith. × 300.

is a very gradual process. A portion of this strand which is towards the medulla becomes differentiated into xylem, and the part on the side of the cortex develops into phloëm. A small patch forming the middle part of the strand is left unchanged and it retains its meristematic condition. These bits of cambium are called **fascicular cambiums** to distinguish them from the patches of cambium formed later in the medullary rays, which are called **interfascicular cambiums.**

A stem is an elongated structure consisting of many bits superposed one above the other, the limits being the places where the leaves are inserted. Every piece is made up of cells, most of them being parenchymatous. The parenchymatous cells show a great activity at a certain period of their life. All the cells except those of the xylem are full of protoplasm. The vascular bundles run through the mass of parenchyma longitudinally and, at every node, a few strands of the vascular bundles leave the stem and enter the stalk of the leaf.

The stem is connected with the root and so the vascular strands of the stem and the root are continuous. On the other side the bundles of the leaf are also continuous with those of the stem.

The growing points and the parenchymatous cells must be supplied with food materials, and the assimilated food materials should be transported from the manufacturing cells. For this purpose special passages should exist. Vascular bundles are such special passages. The woody portion of the vascular bundle conducts the raw solution from the root to the manufacturing cells. The sieve tubes carry the organic material which has been built up in these cells to all those places where new cells are to be formed.

The medulla is an important portion only in young stems. In older stems this consists of dead cells filled with air. The function of the pith in young stems is to swell up the axis and accelerate its growth in length. Another function is the storage of reserve substances.

The medullary rays are somewhat elongated in the radial direction, and consist of parenchymatous cells. In young stems these rays are generally broad, and are called **primary medullary rays.** As the stem gets older and older the primary medullary rays get narrower and narrower, because of the formation of new vascular bundles. These rays afford the most convenient passage for the transport of the material in a radial direction. So long as the vascular bundles are isolated, the whole of the medullary ray consists of parenchyma. But as soon as the xylem becomes a continuous ring that part of the ray which runs through the xylem becomes differentiated. The cells become somewhat elongated in the

radial direction and the walls are lignified. In most cases the wood-parenchyma cells of these rays are filled with starch grains. Such medullary rays run right through the xylem, or they may run only to a certain distance. The former are called **primary** and the latter **secondary medullary rays.**

We have now studied the structure of the Sunflower stem in a detailed manner, and this may be taken as the type of a herbaceous stem. In this stem there are three distinct parts, the **epidermis**, the **cortex** and the **stele.** The epidermis has a distinct cuticle and also hairs. It is a protective layer. The cortex consists of several layers of parenchymatous cells, with a few resin ducts. Just below the epidermis the cells of the cortex are somewhat thickened, especially at the corners where the cells meet. Cells having this kind of structure form a tissue called **collenchyma.** We shall have to speak about these kinds of tissues again. The innermost layer of the cortex consists of cells containing starch grains occasionally, and this layer is called the **endodermis** or the **starch layer.**

Within the stele we find a number of isolated fibro-vascular bundles arranged around a broad core of pith. The bundles have between them the medullary rays. Behind the vascular bundle, and between the endodermis and the phloëm, lies the bundle of fibres. The part of the medullary ray lying between the masses of fibres consists of thin-walled parenchymatous cells. The fibre masses together with the part of the ray between them form a continuous ring, just outside the vascular bundles and inside the endodermis. This part is the outermost part of the stele. These layers constitute what is called the **pericycle.** The vascular bundles arise, not quite outside in the stele, but somewhat inside always leaving one or more layers of cells outside. In other words the endodermis will not be found to be in direct contact with the vascular bundles, but it will be separated from the bundles by the pericycle. At first the vascular bundles possess only fascicular cambium, but very soon interfascicular cambium is produced and the cambium becomes a continuous ring. In older portions of the stem, the xylem is a continuous hollow cylinder.

As further examples, we will do well to examine the stems of a few more plants. The stems of *Hibiscus Cannabinus* and *Aristolochia* may be studied next.

Structure of Hibiscus cannabinus stem.—The stem of *Hibiscus cannabinus* is practically similar to that of Helianthus in its structural features. A cross section of the stem reveals a narrow cortex and a fairly large area of pith with the vascular cylinder between. The medullary rays separating the vascular bundles are very narrow, consisting of only one or two rows of cells. The vascular bundles are narrow and numerous. The cambium region is fairly broad and these features make the vascular cylinder appear almost continuous. In older stems the vascular cylinder becomes quite continuous. Another striking character in this stem is the presence of groups of fibres in the phloëm alternating with sieve tubes and thin-walled cells.

Structure of the stem of Aristolochia.—In a transverse section of this stem we see clearly the epidermis, the cortex and the stele. Within the stele there are a number (5 to 11) of vascular bundles separated by broad medullary rays. (See fig. 114.) The vascular bundles consist of the xylem, the phloëm and the cambium between them. The endodermis is clearly seen, because the layers of cells inside in contact with it are thick-walled. Between the endodermis and the vascular bundles we find two distinct bands that are continuous. The layers of cells with thick walls are the fibres and instead of being in the form of isolated bundles, they are in the form of a continuous ring. Below the ring of fibres lies a broad band of parenchyma. These layers

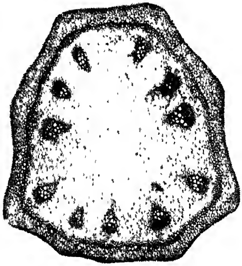


Fig. 114. Fibre bundles (mechanical tissue) in the form of a continuous ring in the transverse section of the stem of Aristolochia as seen under low power.

together constitute the **pericycle.** The epidermis has a cuticle and the central part of the stele is the pith. In this stem, the interfascicular cambium makes its appearance very slowly and gradually.

Woody stem.—As an example of this type we shall choose the stem of *Thespesia populnea*. A transverse section

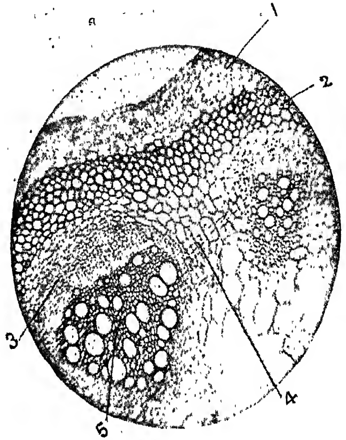


FIG. 115. A portion in the transverse section of the stem of *Aristolochia bracteata*. 1, cortex; 2, pericycle of fibres; 3, phloëm; 4, interfascicular cambium; 5, xylem. × 50.

of a year old stem has a well-marked pith surrounded by an almost continuous hollow cylinder of xylem which has more of wood parenchyma than vessels. Then comes the cambium ring consisting of a few layers of cells that are narrow and quite regular in arrangement. Even in young stems the cambium is more or less a continuous layer. (See figs. 111, 112 and 117.) Outside the cambium there are the phloëm masses arranged so as to form a ring although interrupted by broad medullary rays. The phloëm consists of alternating layers of soft tissue and groups of fibres. The cells of the medullary ray lying between the phloëm masses are somewhat elongated in the tangential direction. The cortex is not broad and it consists of a few layers of ordinary parenchymatous cells

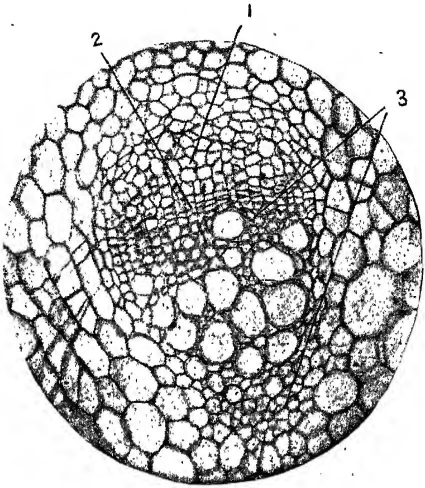
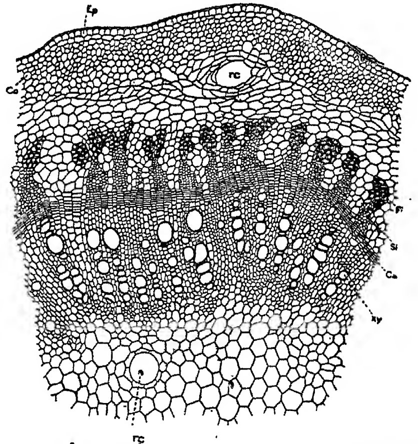


FIG. 116. Transverse section of a single vascular bundle in the stem of *Aristolochia bracteata.* 1, phloëm; 2, cambium; 3, xylem. × 150.



[Fi]g. 117. Transverse section of the stem of *Thespesia populnea.* *Ep*. epidermis; *co*, cortex; *rc*, resin canal; *fi*, fibre bundle; *si* sieve-tube; *ca*, cambium; *xy*, xylem. × 300.

lying beneath a thin band of collenchyma, which is covered by the epidermis. In very young stems outside the collenchyma there will be only the epidermis. But in the case of the older stems, between the epidermis and the collenchyma, we find a few layers of cells all very regularly arranged. This is **cork tissue.** As the dicotyledonous stem increases in thickness due to the activity of the cambium, the outermost layer or the epidermis should also be expected to keep pace with the growth of the stem. Up to a certain limit the epidermis retains the power of extending its dimensions by cell division, but afterwards it loses this power and may get torn.

Long before the time the rupture is likely to occur, cork layers begin to be formed. A layer of parenchymatous cells

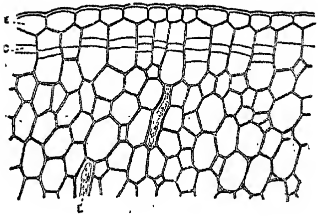
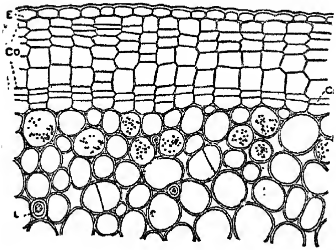


FIG. 118. Formation of cork cells in the cortex of a very young stem of Jatropha. *E*, epidermis; *C*, cork cambium; *L*, latex tubes.

in the cortex, below the epidermis, becomes meristematic and a cork cambium layer goes on producing cells outside on the



119. Formation of cork cells in a stem of Jatropha older than in 118. *E*, epidermis; *Co*, cork cells; *Cc*, cork cambium; *L*, latex tubes.

side of the epidermis, and they gradually change into cork cells.

In the woody type of stem the amount of xylem is great, as the cambium is always active. As regards the component elements of the xylem the primary xylem consists chiefly of spiral vessels and reticulated vessels, though occasionally annular vessels may also be found. But soon after the establishment of the secondary thickening by the cambium ring, the elements of the secondary xylem will be mainly pitted vessels. Of course the cementing elements, wood parenchyma and wood fibres, are formed both in the primary and the secondary wood.

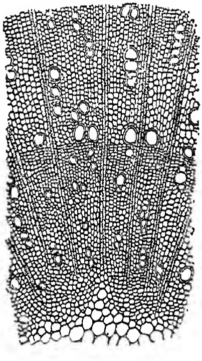


FIG. 120. Transverse section of a portion of the stem of Anona showing medullary rays. × 40.

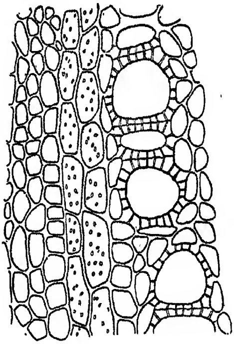


FIG. 121. Transverse section of a portion of the stem of Anona showing a small part of the medullary ray. × 100.

From the study of the structure of the stem of Thespesia it is obvious that a woody stem has fundamentally the same structure that is found in a herbaceous type of stem, though there may be some minor differences. But well-developed woody stems show certain striking features. In a woody stem the most prominent thing is the hard woody cylinder enclosing a very small amount of pith. This is surrounded by the bark which consists of softer tissues. The

bark comes off easily from the xylem and looks as if directly joined to the wood, because the cambium is delicate and is the line of easy rupture.

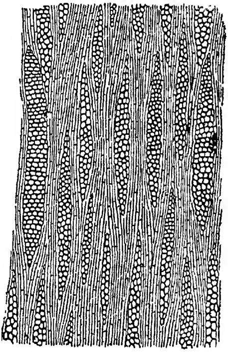


FIG. 122. A tangential section of the stem of Anona through the cortex to show the ends of medullary rays. × 30.

As the stem grows the bark also grows. The bark consists of phloëm, the primary cortex and cork tissue. When

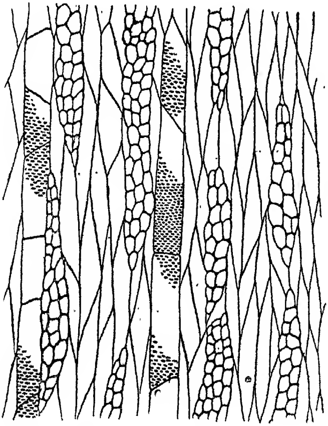


FIG. 123. A tangential section of the stem of Anona through xylem to show the ends of medullary rays. × 100.

the tissues inside a stem increase in extent the epidermis gets ruptured and its place is taken by the cork. In the stem the cork cambium may persist a very long time or it may be replaced from time to time by new ones. After many years the outer layers of the phloëm die and are cast off. The bark adjusts itself admirably to the increasing bulk of the growing stem. The peripheral part of the bark gets broken into furrows and ultimately it is shed.

In the xylem cylinder medullary rays become conspicuous. These are really narrow plates of tissue extending from the cambium to the pith or stopping short of the pith in the radial direction. Their vertical extension is very small and their ends are somewhat lenticular in shape. (See figs. 122, 123 and 124.) Inasmuch as the cells of these rays consist of pitted wood parenchyma cells filled with protoplasm and starch, these link the parenchyma of the xylem and phloëm and form a connected system of living tissue extending inwards and outwards.

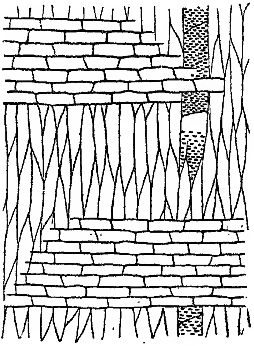


FIG. 124. A radial section of the stem of Anona to show the vertical extension of the medullary ray. × 100.

The difference between a herbaceous stem and a woody stem after all lies in the relative proportions of the different tissues and in the formation of cork. The cambium is more active and there is a large increase in every tissue. Further there is provision for indefinite expansion. If we bear in

mind that a tree has to withstand a great deal of external mechanical force, that large amounts of water pass away from the leaves and that large amounts of reserve food material have to be stored and translocated to various parts, then it becomes obvious that it should have in its stems a large amount of xylem and also a well-developed bark.

Stem of marsh and aquatic plants.—The stems of plants growing in marshes or submerged under water differ in their structure from the other types. The stem of *Herpestis monniera* is quite typical of this kind of stem. In this stem the

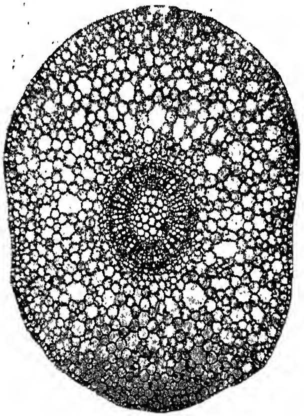


FIG. 125. Transverse section of a stem of *Herpestis Monniera*. × 25.

cortex is broad and full of air-spaces. (See fig. 125.) The stele is confined to the centre of the stem and occupies but a little space. The pericycle and the endodermis are clearly marked off. In the vascular bundles both the xylem and the phloëm are reduced very much and consist of only a few elements. Although the cambium region is well seen, it does not show much activity. (See fig. 126.) Considering the habitat of the plant there is not much need for xylem tissue and hence the great reduction. The need for air is obvious and this is why there is a great development of air spaces in the cortex.

Monocotyledonous type of stem.—In the stems of Cholam, Sugarcane, Paddy, Bamboo, Grasses and Palms (all

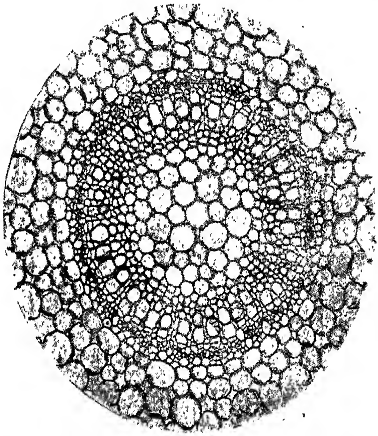


FIG. 126. Transverse section of a stem *Herpestis Monniera* showing only the stele. × 75.

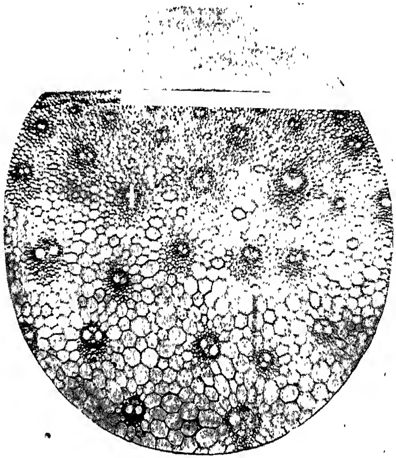


FIG. 127. Transverse section of a monocotyledonous stem. × 50

these are monocotyledons) the vascular bundles are found scattered amidst a mass of parenchymatous cells. Each vascular bundle consists of only xylem and phloëm, without the cambium, and so there cannot be secondary thickening, and such bundles are called **closed vascular bundles**, to

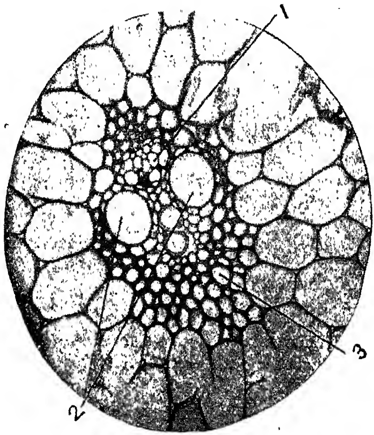


FIG. 128. Transverse section of a single vascular bundle of the Sugar-cane stem. 1, sieve tube; 2, xylem; 3, fibrous sheath. × 200.

distinguish them from the dicotyledonous vascular bundles which have the cambium, and hence are called **open bundles**. A distinct pith or medulla is wanting in the monocotyledonous type of stem on account of the scattered arrangement of the vascular bundles. The cortex is also very narrow. The vascular bundles are far more scattered towards the centre but they are closer near the periphery of the stem.

The vascular bundle consists of only xylem and phloëm. The former consists of only a few vessels, fibres, and wood parenchyma.

The xylem vessels are arranged in the form of a "V" with wood parenchyma and small vessels wedged in between the larger vessels. The phloëm lies close to the xylem. All round the bundle we find fibres forming a kind of sheath,

which is well developed, and for this reason becomes more marked, in the bundles lying near the periphery of the stem.

As already noted the cortex is not a very conspicuous part in this type of stem. The epidermis, as well as a few layers of the cortex, lying immediately beneath the epidermis is generally modified in structure. The cell-walls of the epidermis and those of the cells of the cortex immediately below the epidermis become thickened. Further, as already pointed out, the vascular bundles towards the cortex have very broad sclerenchymatous sheaths. So the peripheral portion of the stem is strengthened by the presence of thick-walled elements enabling it to stand the strain of wind and weight.

Arrangement of the mechanical tissues.—The fibres forming a sheath around the vascular bundles of the monocotyledonous stem and the groups of fibres forming a

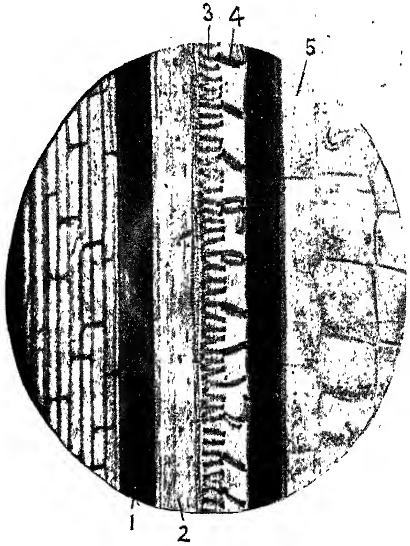


FIG. 129. Longitudinal section of a vascular bundle of the Cholam stem. 1, fibre bundle; 2, pitted vessel; 3, spiral vessel; 4, annular vessels; 5, parenchymatous cells of the ground tissue. × 200.

part of the pericycle in the stems of Sunflower and Aristolochia play a very important part in the life of the plant.

They protect the soft elements of the phloëm. The general arrangement of the fibres in all these cases is very striking and significant.

An engineer or a mechanic will always try to secure the necessary strength in the materials he uses, by the use of the smallest amount of material. For instance, in bridges and roofs instead of using oblong solid beams, girders are used.

A girder consists of two broad pieces, one forming the upper and the other the lower surface with a piece between called the web. If an ordinary beam be fixed at one end

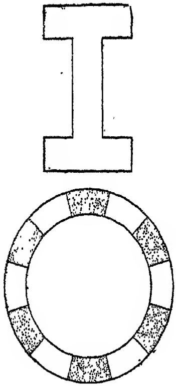


FIG. 130. A girder and a hollow pillar.

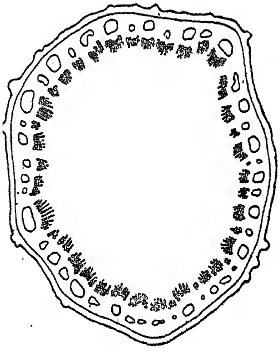


FIG. 131. Fibre bundles in the Sunflower stem. (The larger circles are the fibre bundles and the minute circles in lines are vascular bundles.)

the other end being free, and then a weight be attached to the free end the beam will bend at the free end. Then the upper surface becomes longer and the lower shorter. The central line which is equidistant from both the surfaces undergoes no change. So it is obvious that in the beam the upper and the lower surfaces alone need strengthening, and the web needs it not. In a girder a great amount of material is used

to make the two surfaces strong and the web is generally thin. A girder will bear a greater weight than a solid beam containing the same amount of material. Similarly we find that a hollow cylinder will bear a greater load than a solid one containing the same amount of material. The stems of plants are exposed to strain from the action of the wind. As the stem grows larger and larger, the strain that it has to bear increases. The Sunflower stem, for instance, is exposed to the influence of wind and it has to resist the strain of bending. It has also, at the same time, to carry the weight of leaves, flowers and branches. So there must be in the stem some arrangement which will enable it to withstand

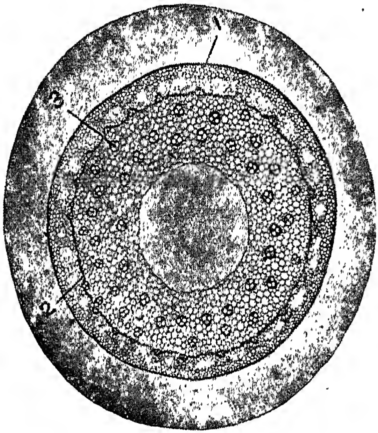


FIG. 132. Transverse section of the stem of *Panicum repens*, 1, epidermis; 2, ring of fibres; 3 fibrous sheath of the vascular bundle. × 15.

the strain of bending. In a transverse section of the flower stem, we find isolated groups of fibres just close to the phloëm and almost near the periphery. The arrangement of the groups of fibres, in this stem, and in this manner, makes it like a hollow cylinder with very great firmness and rigidity at the periphery of the stem. A hollow cylinder is really a combination of several girders.

This kind of arrangement of fibres is seen in many monocotyledonous stems also. For instance, in the stem of *Panicum repens* we find a continuous ring of sclerenchyma

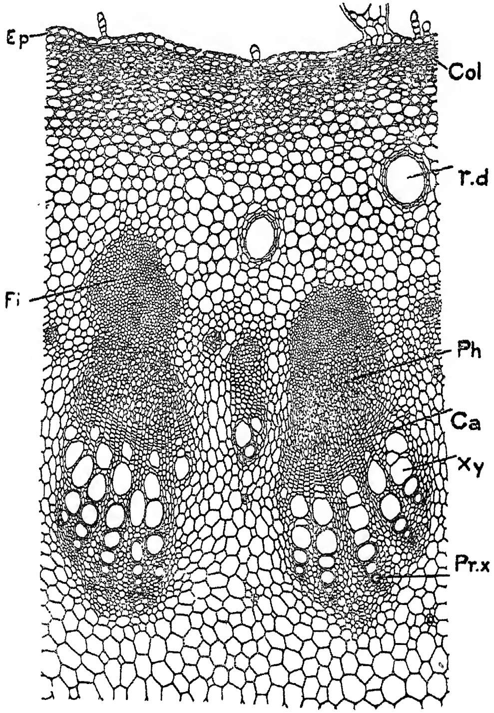


FIG. 133. Collenchyma in the stem of the Sunflower plant. *Ep*, epidermis; *Col*, Collenchyma; *r.d.* resin duct; *Fi*, fibre bundle; *Ph*, phloëm; *Ca*, cambium; *Xy*, xylem; *Pr. x*, primary xylem. × 60.

and also the fibrous sheaths of the vascular bundles. Where such rings are absent we find the peripheral part strengthened by the thickening of the epidermal cell walls and by the development of a larger number of vascular bundles with very pronounced fibrous sheath in the peripheral part of the

stem. As the stem gets older several layers beneath the epidermis undergo thickening of their cell-walls.

This strength giving tissue, consisting of groups of fibres, is sometimes called mechanical tissue. The fibres come into existence gradually. So in young stems we do not find these fibres so well-formed and arranged. They are either absent or in the course of formation. Younger parts of stems also require a certain amount of strengthening at the periphery, as they have also to withstand the strain of wind and weight.

As all the parenchymatous cells in the younger parts are active, it is necessary to have some kind of mechanical tissue which would give rigidity and at the same time be elastic, to allow the cells to grow. Fibres are inelastic and rigid. Therefore they are out of question. Some other kind of tissue must be formed. The parenchymatous cells of the

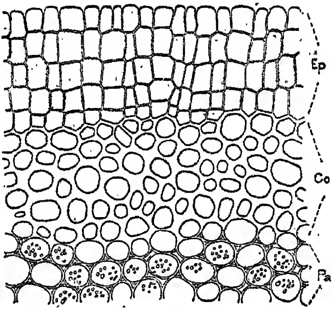


FIG. 134. Collenchyma in the stem of Nerium. (Transverse section.) *Cu*, cuticle; *Ep*, many layered epidermis; *Co*, collenchyma; *Pa*, parenchyma. × 200.

cortex below the epidermis become thickened at the corners where two or three cells meet. These cells form a kind of tissue and we have already spoken of this tissue and it is called **collenchyma**. Thus we have two kinds of tissues to serve as mechanical tissue. Collenchyma consists of living cells and is best suited for young stems, because it may change into ordinary parenchyma when it is no longer needed; the fibres on the other hand are dead cells and so are of no other use.

Both the root and the stem of dicotyledons are capable of increase in their thickness to any extent on account of the presence of the cambium. This increase in thickness is called secondary thickening. Under normal conditions growth or increase in the number of cells, which naturally leads to the increase in the different kinds of tissues, is confined to the cambium. But under abnormal conditions parenchyma that has ceased to divide and grow may once again become active and give rise to different kinds of tissues. When a stem is cut across or injured various tissues are exposed to the air. Most of the cells of the cortex are living cells and so, when pressure is removed by the injury, all these cells swell and some of them lying somewhat deeper begin to divide. As the result of this activity a mass of cells is formed at the injured area and the outermost cells become changed into the protective tissue, cork. This mass of cells brought into existence by this abnormal activity is spoken of as **callus** and the process is termed **callus-formation.** All the wounds caused accidentally or consciously by men in tree trunks and branches get healed by the process of callus-formation.

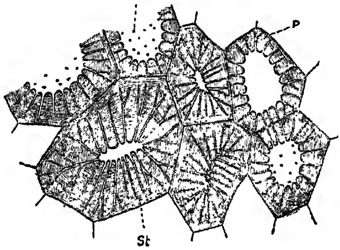


FIG. 135. Sclerenchyma from the stem of Nerium. *St*, laminations ; *p*, pits. × 400.

From a study of the structure of the stem we see that it is only a mass of cells in which are embedded cells or groups of cells variously modified. The main bulk of the stem consists of thin walled parenchymatous cells. For the sake of

clearness we may classify all the tissues occurring in a plant body as follows :—

(*a*) **The formative tissue**—

(1) Meristem cells of the growing points.

(2) The cambiums.

(*b*) **The protective tissues**—

(1) The epidermis and (2) the cork tissue.

(*c*) **The conducting tissues**—

(1) The lignified vessels and (2) the sieve tubes.

(*d*) **The ground tissue**—The parenchymatous cells.

(*e*) **The mechanical tissues**—

(1) Sclerenchyma and (2) Collenchyma.

(*f*) **Some special tissues**—

(1) Laticiferous tissue.

(2) Resin ducts.

(3) Oil glands and mucilage cells.

CHAPTER VI

THE LEAF

THE leaves are the most conspicuous parts of a plant and they are also very important organs of a plant. It is a matter of common knowledge that leaves vary a great deal in size, shape and character. And yet most leaves are delicate and have a thin flattened portion called the blade or the lamina.

A leaf is an outgrowth of the stem like its branches, but with this difference, namely, a branch is merely the repetition of the stem, whereas a leaf differs very much from a stem in its structure. From a study of leaf buds we have learnt that leaves appear as small outgrowths on the surface at the growing points and that they develop in aeropetal succession. Leaves are arranged on the stems in definite positions and in some regular order.

A typical leaf has three parts, the blade or the expanded portion, a stalk or the petiole and the basal portion of the leaf which connects the leaf with the stem. All leaves do not possess all these three parts. For instance, we have leaves, such as those of Lactuca, Sonchus and Argemone without stalks. The leaf blade, on the other hand, is very well developed in most of the flowering plants. Similarly the basal portion of the leaf must be expected to be present in all plants. Young leaves which are enfolded in the bud do not possess stalks, or if they happen to have them they are very short and almost invisible. However, the stalk develops subsequently, and elongates after the unfolding of the leaves. This is so, because in the enfolded leaves the basal portion and the lamina become developed very much earlier than the stalk or the petiole.

From the basal portion of the leaves outgrowths arise in many plants. Generally two outgrowths, one on each side, are seen and they are called **stipules**.

In very many plants the stipules are small and not prominent. There are also plants in which the stipules are very conspicuous and large. The Peepul (*Ficus religiosa*),

the Banyan (*F. bengalensis*), the Jack tree (*Artocarpus integrifolia*) and *Cassia auriculata* have large stipules. In

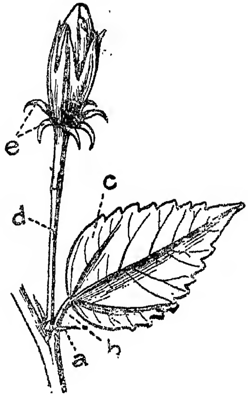


FIG. 136. Parts of the leaf of *Hibiscus Rosa-sinensis*. *a*, stipule; *b*, petiole; *c*, lamina or blade; *d*, peduncle; *e*, bracteoles forming an epicalyx.

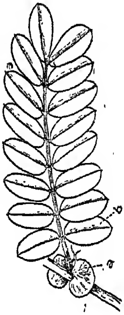


FIG. 137. Parts of the leaf of *Cassia auriculata*. *a* stipules; *b*, leaflets.

the first three the stipules serve to protect the young leaves in the bud; they are large and semilunar in *Cassia auriculata*. Sometimes they are tubular (Ochrea) as in *Polygonum glabrum*.

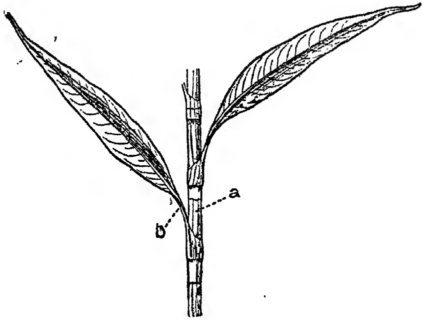


FIG. 138. Tubular stipules of Polygonum. *a*, stipule; *b*, petiole.

When leaves are young they are generally folded in different ways. In many plants the two halves of the blade

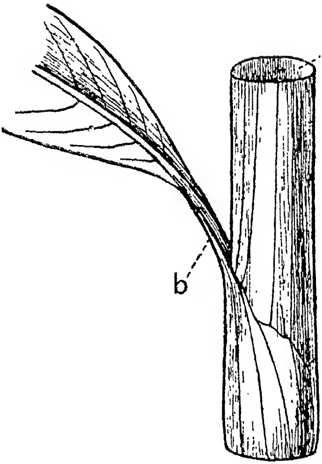


FIG. 139. Tubular stipule of Polygonum. *a*, tubular part; *b*, stalk of the leaf. (Four times the nat. size.)

are folded along the midrib in such a way that the inner surface and the edges of the blade meet, as in Anona, Abutilon, Thespesia, Morinda and Tephrosia. This kind of folding is called **conduplicate**. Sometimes the leaf is rolled on itself in such a manner that one margin being rolled towards the midrib remains inside and the other over it outside, as in Musa and Canna, and the folding is termed **convolute**. It is not unusual to find both the margins of a leaf rolled inwards towards the midrib as in Nymphæa, Nelumbium, Ottelia and Viola and this is described as **involute**.

FIG. 140. Terminal bud of *Ficus bengalensis*, protected by stipules.

As already remarked, of all the vegetative organs of a plant the foliage leaves are the most important, because the

FIG. 141. Young leaves just emerging from within the stipules in the young leaf bud of Ficus.

formation as well as the transformation of organic matter takes place in them. The work that leaves have to do is very complicated and varied. The green colour enables them to do the work of forming organic matter under the influence of sunlight. This special work of the leaf cannot be carried out unless the leaves are exposed to sunlight. So we expect leaves to be disposed on the axis in such a manner that all the leaves may get as much light as possible. And yet too much light is injurious to leaves. The adjustment of the position of the leaves with reference to light is therefore a very delicate one.

In most plants the leaf blades maintain a horizontal position so that a large number of light rays may fall on them. If the light gets too intense, either the leaf blade will

change its position or the twig bearing the leaves will shift its position.

Every green plant produces as many leaves as possible, and their position with regard to the light will be such that all the leaves may get sufficient light, without shading one another to any large extent. Leaves generally appear to be arranged in various ways on the stem, but on close examination it will be found that either a single leaf originates at each node, or two or more spring from it.

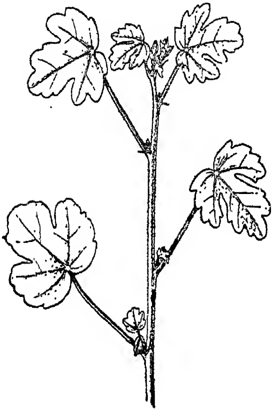


Fig. 142. Alternate leaves of *Pavonia zeylanica*.

When only one leaf is borne by the stem at the nodes, the leaves will be found arranged spirally around the stem or alternately. This arrangement of leaves on the stem (or **phyllotaxis**) is said to be **alternate.** Leaves are said to be **opposite,** if two leaves arise opposite to one another from the same node. If there are more than two leaves at a node, they are said to be **whorled.** Leaves are opposite in

Fig. 143. Opposite leaves of Morinda. a, a.

Morinda, Calotropis, and Vinca. They are whorled in Nerium, Alstonia and Clerodendron. As examples for the alternate phyllotaxis we may mention Thespesia, Abutilon, Pavonia and Melia.

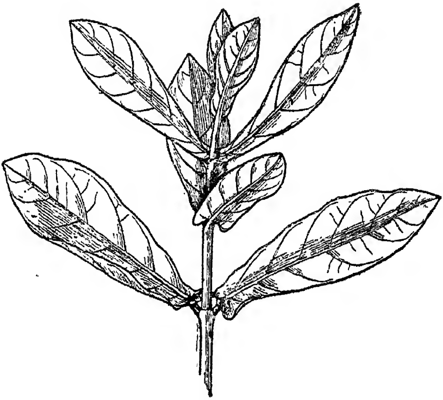


FIG. 144. Opposite leaves of Calotropis.

In stems with alternate leaves no two successive leaves will be found to be one exactly above the other and yet, the leaves will be in vertical rows. Between two successive leaves on the same vertical line, a number of leaves will be found, but at different heights and in different positions. To make out the arrangement of the leaves in such cases, a close examination of the nodes of a normally growing shoot is necessary. As an example a branch of Thespesia, or Abutilon may be taken. In these branches any leaf chosen will be exactly above or below the sixth leaf and the five leaves spirally arranged round the stem. The spiral will consist of two turns around the stem and the

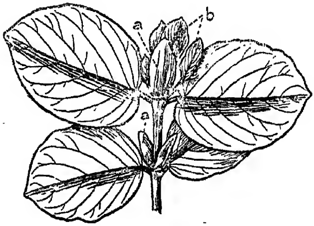


FIG. 145. Opposite leaves of Stephegyne.
a, stipules ; b, young leaves.

first leaf will be separated from the second by a space equal to two-fifths of the circumference. If the circumference were one inch the first leaf will be two-fifths of an inch apart from the second, and the second the same distance from the third and so on. In a spiral of five leaves we get five vertical rows arranged round the stem at equal distances. We also meet with spirals having two, three, or four leaves or more.

When the leaves are opposite the successive pairs will be at right angles to one another. In other words the leaves at

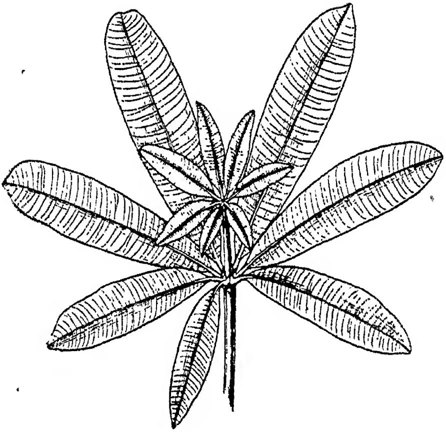


Fig. 146. Whorled leaves of *Alstonia scholaris*.

any one node will be across the leaves of the nodes immediately above and below it. This arrangement of the leaves is called **decussate** arrangement. (See fig. 144) When the leaves are in a whorl, the leaves of the alternate nodes are exactly one above the other, and the leaves of the successive nodes will be found on different vertical lines side by side.

The phyllotaxis will become clear, only if we remember that the leaves require the play of sunlight on their blades. Usually the most advantageous position for the leaf blade is to place its surface across the direction of the rays of light. But if the light becomes very intense, this position is certain to injure the leaf blade. So, under such circumstances, the leaf should be able to shift its position. When the sun's rays pour

straight down, the leaf will shift its position, so that the blade may be parallel to the rays instead of being at right angles. Almost all leaves possess the power of changing their position according to the nature and the intensity of the light of the sun.

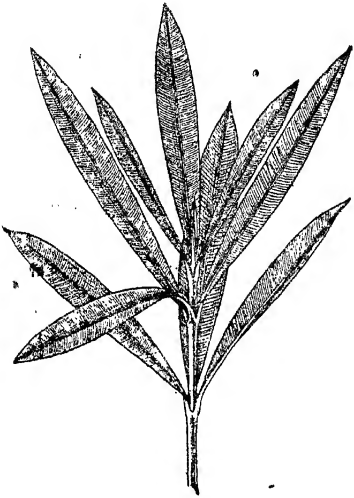


Fig. 147. Whorled leaves of Nerium.

As all the leaves of a plant need light, it is obvious that they should grow in such a manner, as not to shade each other. One of the means by which the leaves are helped in this matter is the phyllotaxis. There are also other means, besides the phyllotaxis, by which the leaves avoid the shading. Choose some erect branches from a plant, say *Acalypha indica* or an Amaranth, and look down upon them from above. Then the leaves will be found arranged in rows round the stem, in such a manner that the space round the stem is utilized to the greatest possible extent. Further, the leaves below are not shaded by those above, because the petioles of the former are longer than those of the latter. Again the size of the leaf blade also has some bearing on the disposition of the leaves round the stem. If the leaves

have broad laminas, the rows round the stem will be three or four; there will be five or six rows, when they are moderately broad; the rows will be many in cases where the blade is very narrow. Whatever the number of rows around the stem, all the leaves get their share of light, because the rows are not likely to shade one another. But, in the same row, leaves above are likely to throw those below into shade. As a matter of fact this does not happen so as to interfere with one another. By the adaptation of the length of the internode and the direction and length of the leaf-blade, shading is avoided.

Thus it is seen that the adjustment of the leaves for the sake of light is very varied and complicated. In some cases the leaf surfaces present beautiful mosaics and rosettes. For instance in many Solanaceous plants, such as *Physalis minima*, the leaves are not all uniform in size and so the leaves arrange themselves in a mosaic fashion.

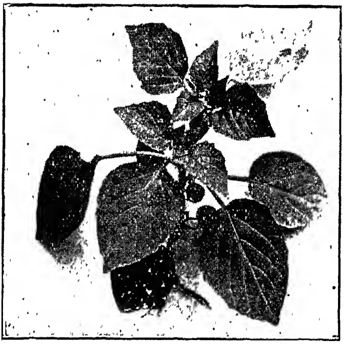


FIG. 148. Leaf mosaic of *Physalis minima*.

Many plants of the order Compositæ may be cited as examples for the rosette habit of the leaves. The leaves in *Lactuca Heyneana*, Sonchus and some Blumeas are mostly confined to the base of the plant. In other words, the leaves are radical. In all these plants the leaves are narrow at least in the lower part and so they are disposed round the stem, so as to form a rosette. It is easy to give more examples; for instance, Trapa, Elytraria and *Elephantopus scaber*.

The same principle, that the leaves should spread themselves so as to enable all the leaves to be lighted and, at the same time, avoid shading one another, is very well brought home by the heads of trees. For instance, the heads of trees

such as those of the Banyan are generally found covered by

FIG. 149. Leaf mosaic of Pellionia.

leaves so as to form a framework or covering with as few gaps as possible. To enable all the leaves to obtain sufficient light, this is the best possible arrangement. If we look at the head of the same tree from inside and from near its trunk towards the branches, we find large spaces between boughs and twigs, and no leaves are found distributed in these gaps.

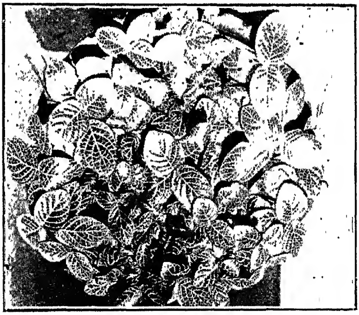
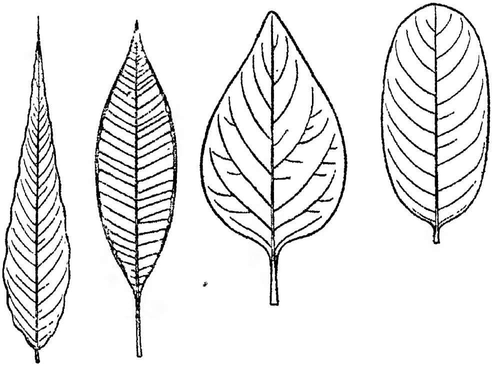


FIG. 150. Leaf mosaic of Fittonia.

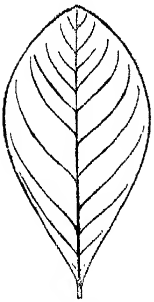
Shape of leaves.—Leaves vary very much in their shape. For purposes of description names are given to the shapes that are striking. A leaf whose lamina is narrow with the sides parallel, is said to be **linear.** Leaves of grasses and



151. 152. 153. 154. 155.

FIGS. 151 to 155. Shapes of leaves; linear, lanceolate, elliptic, ovate and oblong leaves.

those of the cereal plants are linear. When a leaf is somewhat broad at the middle or a little below and tapers towards the apex, as in Nerium, Polygonum and Polyalthia it is described as **lanceolate.** A leaf is **oblong** when the margins are almost straight and the blade uniformly broad. Guava, Calotropis and Banyan leaves are good examples of oblong



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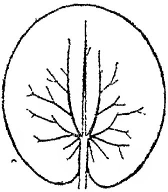

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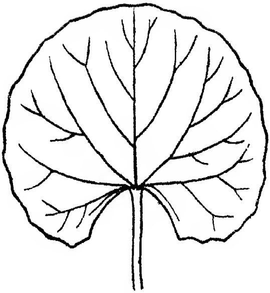

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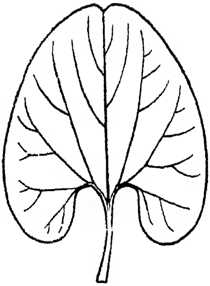


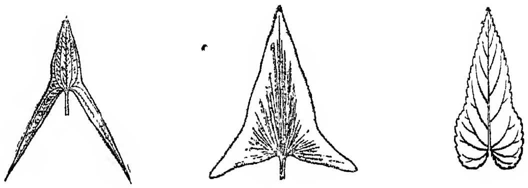
159.

FIGS. 156 to 159. Shapes of leaves; obovate, orbicular, reniform and cordate.

leaves. When the leaf blade is broad and rounded at the base and also tapering to a point at the apex, it is described as **ovate**. Leaves of *Hibiscus Rosa-sinensis*, *Acalypha indica*, *Solanum nigrum* and *Physalis minima* are good examples. When the blade is broader at the apex and narrowed towards the base, as in the leaflets of *Cassia obovata*, it is **obovate**. Leaves like those of Nelumbium are described as **orbicular** or **rotund**. Sometimes the blade is hollowed out at the base, and pointed at the apex so as to be roughly like the heart spot on a playing card, and such are called **cordate** or **heart-shaped**. The leaves of Thespesia and Aristolochia may be cited as examples. If the apex be rounded, instead of being pointed, the outline is said to be **reniform** or **kidney-shaped**. The leaves of *Centella asiatica* are reniform. There are some leaves whose lamina resemble somewhat an arrow head in their shape, and such leaves are **sagittate**. Several species of the natural order Aroideæ have sagittate leaves. If the basal lobes of such a blade are straight and at right angles to the blade, the leaf is then **hastate**. If the basal lobes are rounded and prominent, the leaf is said to be **auricled**.

Margin of leaves.—The leaf margin is **entire** when it is quite even without any indentations. It is **dentate**, if the margin is cut up into prominent teeth, as in *Hibiscus Rosa-sinensis*; **serrate** if the teeth are small and directed upwards, as in *Acalypha indica*; **crenate** when the teeth are rounded, as in *Bryophyllum calycinum*, *Centella asiatica* and

Stachytarpheta indica. Sometimes the margins of leaves become deeply indented and then the leaf is said to be **lobed,** if the cut does not go more than half way to the centre, as in the cotton leaf, and if it is deep reaching the middle of the leaf, as in Lactuca and Radish, then the leaf is said to be **cleft.**



160. 161. 162.

FIGS. 160 to 162. Sagittate, hastate and auricled leaves.

When a leaf is lobed, the lobes are arranged either on the sides of the midrib as in Lactuca and Radish, or they may all spread like the fingers of a hand, as in Jatropha and *Hibiscus ficulneus*. The former is described as **pinnate** and the latter **palmate** or **digitate.** Sometimes the lobing becomes so deep as to cut the blade into distinct pieces, so that a piece may be plucked off without in the least affecting the others. In such cases the leaf is said to be a **compound leaf.** The leaflets may

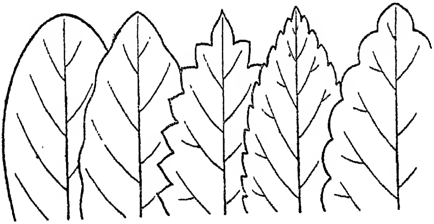


FIG. 163. Leaf margins. Entire, undulate, dentate, serrate and crenate margins respectively.

either be disposed pinnately as in *Cassia auriculata* and *Cassia siamea* or palmately as in *Eriodendron anfractuosum* and *Gynandropsis pentaphylla.*

The division of lamina may take place only once and then the leaf is simply compound, or the leaflets may become divided further, as in the case of Moringa, Cardiospermum, *Acacia arabica*, *Melia Azedarach* and *Millingtonia hortensis*. Then the leaf is described as **bi-** or **tri-pinnately compound** according to the division.

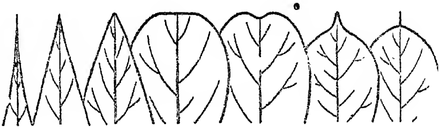


FIG. 164. Leaf apex. Acuminate, acute, obtuse, truncate, retuse, cuspidate and mucronate respectively.

Apex of leaves.—If the apex of a leaf tapers to a point gradually it is said to be **acuminate,** and if it is merely sharp pointed it is **acute.** The apex is **obtuse,** when it is rounded. Sometimes the apex will be straight as though cut off and then it is **truncate,** and if there is a notch, it is said to be **retuse** if the notch is shallow, and **emarginate** if it is deep. In some cases we see a sharp point projecting from the apex and then it is said to be **mucronate.** We meet with leaves having a triangular piece at the apex and then it is said to be **cuspidate.**

Kinds of leaves.—The organ directly concerned in the work of manufacturing organic substances is the foliage leaf. This is the kind of leaf which is of very general occurrence. Sometimes leaves are forced to do some kind of work, other than the preparation of organic substances. For instance, in seedlings, the **cotyledons** in most cases have very little to do, at any rate in the beginning, with the work of making organic stuff. The work that the cotyledons are mainly concerned in is to store food and make it available to the growing seedlings.

Another kind of leaf occasionally met with in some plants is what is known as the **scale-leaf.** These leaves are met with in connection with scaly buds. In Mango trees when growth is at a standstill the terminal buds at the ends of twigs are covered by small scales. These scales are really leaves

remaining undeveloped and small so as to afford protection to the growing point. (See figs. 89 and 90.)

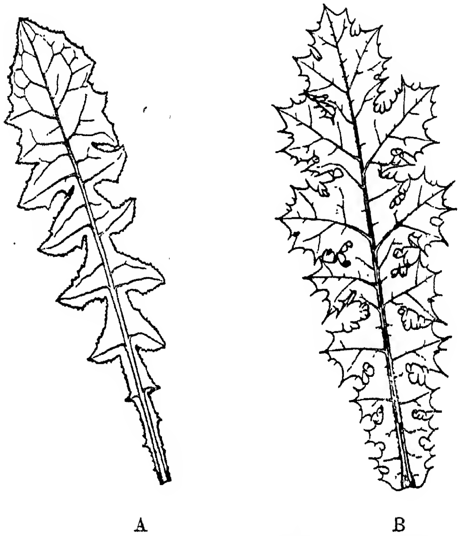


FIG. 165. Pinnately lobed leaves of A, Lactuca and B, Argemone.

And yet another kind of leaf is the **bract** found in connection with the flower. Bracts are generally small, but in some

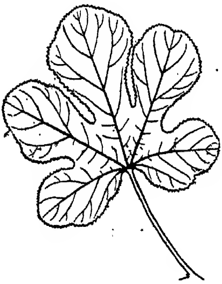


FIG. 166. A digitately lobed Hibiscus leaf.

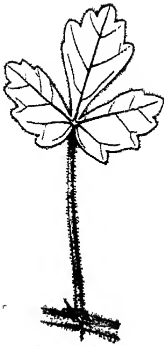


FIG. 167. A digitately deeply lobed leaf of Pavonia.

plants they are large. For instance, in the terminal branches of the plant *Gynandropsis pentaphylla*, the foliage leaves

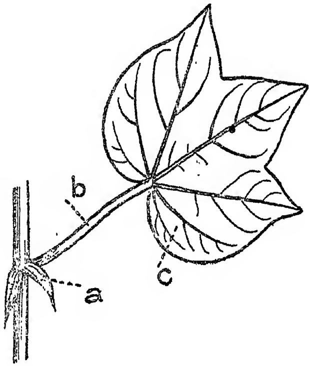


FIG 168. Digitately shallowly lobed cotton leaf. *a*, stipule *b*, petiole ; *c*. blade.

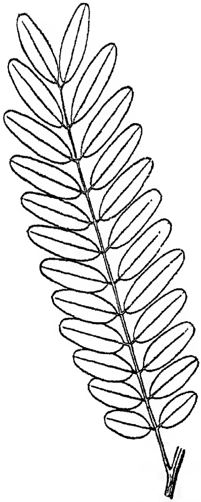


FIG. 169. Paripinnate compound leaf of *Cassia siamea*.

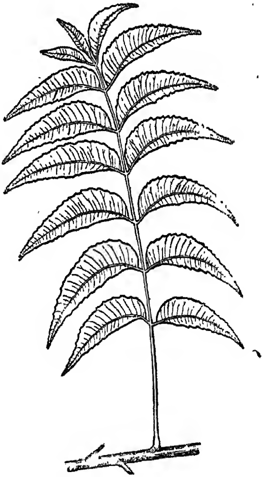


FIG. 170. Impari-pinnate leaf of *Azadiracta indica*,

gradually pass into bracts and so, they are very conspicuous and leaf-like.

Modified leaves.—There are a number of plants feeding on insects. They do not thrive well, unless they obtain insects. In these plants there are adaptations of a special kind to enable them to catch and digest small insects. As examples of such plants we may mention Drosera (*D. Burmanni,*

FIG. 171. Bi-pinnately compound leaf of *Acacia arabica.* *a*, stipular thorn ; *b*, petiole ; *c*, gland.

D. peltata and *D. indica*), Utricularia (several species) and the pitcher plant Nepenthes. In Drosera the leaves are provided with glandular hairs secreting mucilage in such profusion as to imprison the insects, when the hairs come in contact with them. The leaves of Utricularia are modified into bladders with trap doors to catch insects. In the pitcher plants the leaves are prolonged at the apex into long processes ending in cups. These cups or pitchers as they are called, contain a liquid. The insects are allured by these pitchers so that they may fall into and get digested by the water contained therein.

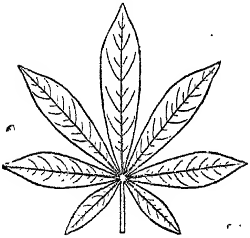


FIG. 172. Palmately compound leaf.

Leaves are able to produce organic matter, as they contain chlorophyll. Young parts of plants are also able to do this because they also contain the green colouring matter. There

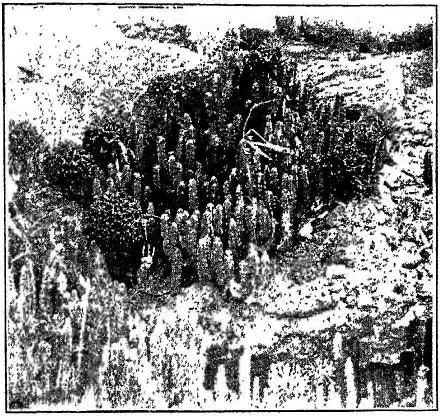


FIG. 173. Boucerosia. Note the leafless fleshy stems (cladophylla).

FIG. 174. The Pitcher plant.

are many plants without leaves, as in the case of the prickly-pear. In such plants the chlorophyll grains become imbedded in the cells of the cortex of the stem. Such stems look quite different from the ordinary stem and they are called **cladophylla.**

In some leaves the petiole develops into a flat structure very much resembling the leaf and the blade either remains very insignificant, or it is not at all developed. Such petioles are called **phyllodes.**

As examples of cladophylla we may mention the stems of Boucerosia, Opuntia, Casuarina and some Euphorbias. Phyllodes are found in *Acacia auriculiformis* and in *Parkinsonia aculeata.*

Petioles have sometimes wings on both sides as in the orange leaf and in the compound leaves of some species of Vitex and *Filicium decipiens.*

The internal structure of leaves.—The leaf-stalk or the petiole does not differ much from the stem in internal

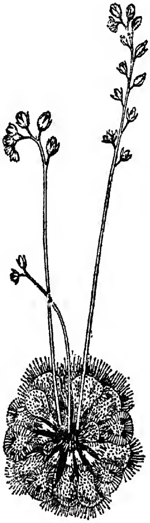


FIG. 175. *Drosera Burmanni.* The entire plant.

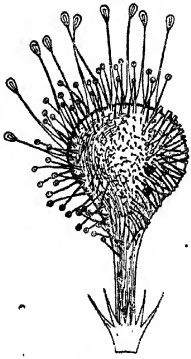


FIG. 176. A single leaf of *Drosera Burmanni* with glandular hairs (Five times the nat. size.)

structure. In the petiole the vascular bundles are arranged generally like a semi-circle, especially the larger ones. There are also smaller bundles between the larger ones. The cambium does not persist in these bundles, because there is no need for secondary thickening. The xylem lies towards the upper surface and the phloëm towards the lower.

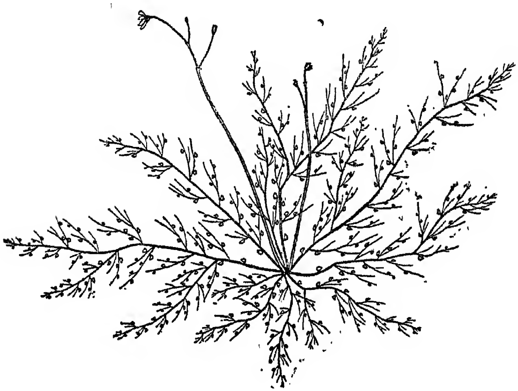


FIG. 177. *Utricularia exolaeta.* (Entire plant.)

The lamina of an ordinary leaf consists of a mass of parenchymatous cells filling up the meshes of the network of veins, which is a prominent feature of the foliage leaves. This network of veins not only supports the leaf tissue, but also serves as a channel for carrying water to the cells in the meshes of the network. It also prevents the tearing of the leaf blade and keeps it quite flat. As striking examples of the network of veins, we may mention the leaves of *Ficus religiosa*, Quisqualis, Dolichos and Antigonon.

A leaf considered from an anatomical point of view consists of three parts. They are an epidermis covering both the surfaces of the blade, **Chlorenchyma** or the mass of parenchymatous cells having chloroplastids imbedded in them and the network of veins.

The epidermis consists of flattened cells all fitting closely together, and they do not contain chlorophyll grains. The

lower epidermis differs from the upper epidermis in having the characteristic openings, the **stomata.** Each stoma (which simply means a mouth) consists of a pair of semi-lunar cells bounding the opening. These cells are called the **guard cells** and they contain chlorophyll grains. Further, these

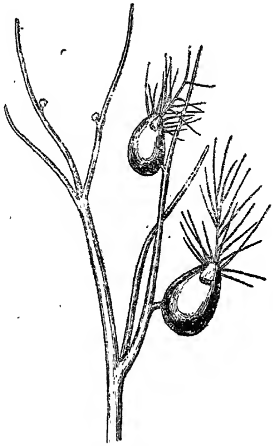


FIG. 178. A branch of *Utricularia exolaeta*, with bladders. × 10.

guard cells are capable of changing their shape and so vary the size of the opening. These stomata are generally confined to the lower epidermis of leaves, but there are also leaves having stomata on both sides. The number of stomata is generally very large and it may be anything from 50,000 to 450,000 or more to the square inch.

The parenchymatous cells, forming the bulk of the leaf tissue (Chlorenchyma) in leaves with the upper and the lower surfaces well marked, are arranged in two distinct ways. In the upper portion of such a leaf one or more layers of cells are elongated vertically and lie side by side without much of intercellular space. This is called the **palisade parenchyma.** The parenchyma lying below the palisade parenchyma consists of cells arranged so as to have a large number of spaces, and hence this part of the mesophyll is termed **spongy parenchyma.**

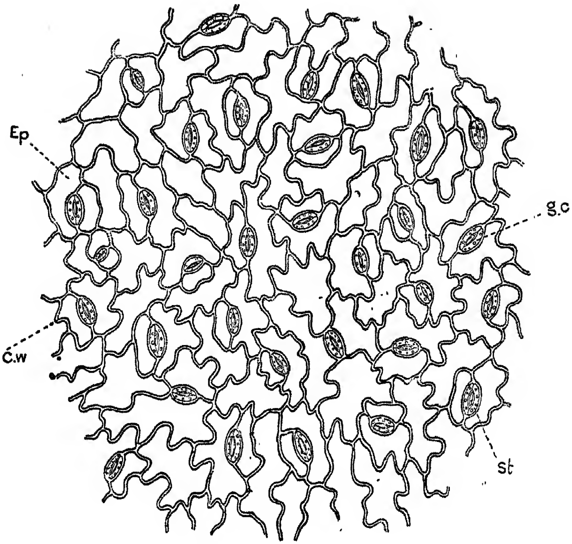


FIG. 179. Epidermis from the lower surface of *Dolichos Lablab* leaf. *Ep*, epidermal cells, *C.w*, cell-wall; *g.c*, guard cells; *St*, stoma. × 300.

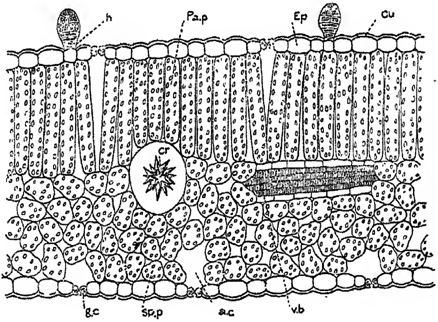


FIG. 180. Vertical section of Gogû leaf. (Highly magnified.) *Cu*, cuticle; *Ep*, epidermis; *h*, glandular hair; *Pa.p*, palisade parenchyma; *Cr*, calcium oxalate crystal; *sp.p*, spongy parenchyma; *v.b*, vascular bundle; *a.c*, air chamber; *g.c*, guard cells of the stomata.

This distinction of mesophyll, into a compact palisade parenchyma and spongy parenchyma, is liable to variations according to the habit and the species of the plant. In the leaves of a plant growing in an open place exposed to the

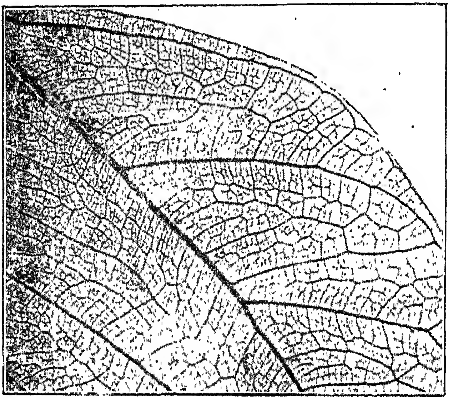


FIG. 181. A portion of the "skeleton" of a leaf of *Ficus religiosa.*

sun, the palisade parenchyma will be deep and will consist of several layers of cells, e.g., leaves of Nerium, Calotropis and the Banyan. Plants growing in a shady place have leaves with a single layer of palisade cells, e.g., Vigna and Dolichos. In the case of plants whose leaves are exposed to the light of the sun on both the sides, this separation of the mesophyll into two kinds of parenchyma does not exist. For instance, the leaves of grasses do not show this separation, but the whole of the mesophyll consists of compactly arranged parenchymatous cells.

The most prominent structure in a leaf is its network of veins, and this part may very well be observed by allowing leaves of plants to rot. The mesophyll and all the soft tissues decay, leaving only the hard vascular frame work. This network of veins is sometimes called the "skeleton" of the leaf. (See fig. 181.)

CHAPTER VII

THE PLANT CELL

FROM a study of the structure of the different parts of a plant we learn that they are only masses of cells, variously modified in shape and size. The cells are generally very small and vary in length from about 1/1000 inch to 1/80 inch. Inasmuch as every part of a plant is made up of cells we must consider them as the structural units of plants, or as their elementary organs. A cell, it must be remembered, is a morphological as well as a physiological unit.

The name cell was at first introduced by Robert Hooke about the beginning of the seventeenth century to the structural units of a thin slice of cork, because when viewed under the microscope it has the appearence of a honeycomb. Until about the middle of the nineteenth century the importance of the living contents of the cell was not fully recognized. The fact that the protoplasm is the essential part of the cell was established by Schleiden so far as plants are concerned. Although the term cell is not at all an appropriate one, it is retained in order to avoid confusion, and its significance is now extended to include the living contents protoplasm also. The protoplasm of an individual cell is sometimes called a **protoplast**.

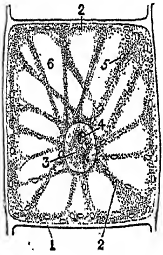


FIG. 182. Vegetable cell; 1, cell-wall; 2, strands; 3, nucleus; 4, nucleolus; 5, chloroplasts; 6, vacuole.

Cells constitute the essential part of a plant body, and everything that a plant does as a living being is really done by the protoplasm. Inasmuch as all the chemical changes in a plant are initiated, and kept up by the living substance we have to consider the protoplasm to be the seat of all vital processes.

About the complexity of the cell a botanist writes :—

"The vital processes exhibited by a cell indicate a complexity of organization and a minuteness in the details of its

mechanism which transcend our comprehension and baffle the human imagination, to the same extent as do the immensities of the stellar universe."

Protoplasm.—Protoplasm in the living state is more or less a tenacious colloid having a semi-liquid consistency. Ordinarily it is clear, although it often presents a granular appearance. Its consistency, general appearance and its disposition in the cell depend mainly on the nature of the activities of the cells and upon the stage of development. In very young parts which are in the embryonic stage protoplasm fills the cell completely and it is compact with a relatively large conspicuous nucleus. Besides the nucleus, several small bodies may be found imbedded in the general plasma of the cell occupying the space between the cell-wall and the nucleus. This general plasma is called **cytoplasm.** As the embryonic cells get older the appearance of the cytoplasm varies. At first small spaces appear which gradually increase in size and become the conspicuous **vacuoles.** In adult cells the cytoplasm is reduced to a layer, closely adherent to the cell-wall and connected with the more or less centrally placed nucleus, by means of strands running across the cavity in different directions. Ultimately all these large vacuoles may coalesce into a single cavity in some cells, reducing the protoplast with its attendant organs to a thin peripheral layer adhering to the cell-wall. When in this condition the protoplasm is sometimes termed "the primordial utricle."

Although enclosed by a cell-wall, the protoplasm frequently shows movements which may readily be seen in the long cells of the leaf of Vallisneria, or in the staminal hairs of Cyanotis. Other particularly favourite objects for this purpose are the hairs in the calyx of young buds of Cucurbita or Benincasa and the internodes of Nitella or Chara.

In the case of Vallisneria the movement of the protoplasm is in one direction only. There is only one current which is continuous and it follows the cell-wall in the same direction. In some cells the direction of the movement may be clockwise and in others anti-clockwise. In these cells the protoplasm is reduced to the primordial utricle. This kind of movement is termed **rotation.** Many aquatic plants show rotation in their cells.

The streaming movement in the protoplasm of the cells of the hairs of Cucurbita or Cyanotis is more complicated. The protoplasmic threads traversing the cell cavity as well as the cytoplasm lining the cell-wall show the movement. Within the same cell the movement will be in one direction in some strands and in others in the opposite direction. Occasionally there may be in the same strand streaming movements in opposite directions, one on each side. Such movements go by the name **circulation.**

Protoplasm is capable of perceiving different kinds of stimuli and responding to them in a suitable manner. This power possessed by the protoplasm is called **irritability.** The specific nature of each cell as well as that of the entire plant is dependent upon the control exercised by the protoplasm. It initiates and carries out not only the various processes connected with the nutrition of the plant, but also those connected with both sexual and asexual reproduction.

A very considerable part of protoplasm in the living condition consists of water. Water is absolutely necessary for the life of the protoplast and so we always find water associated with it. Chemically viewed protoplasm is not at all a simple substance. Its exact chemical composition has yet to be determined. From available data we know that it consists of highly complicated unstable substances which are subject to continual changes. Proteids form the largest part of it. Active protoplasm is usually alkaline in reaction, although under certain conditions it may give a neutral reaction. Protoplasm coagulates under high temperature, and also when it is brought into contact with acids and alcohol.

Cytoplasm.—The cytoplasm is spongy or alveolar in appearance. Sometimes it may also present a fibrillar structure. It is granular, but when closely examined a clear exterior free from granules becomes apparent. This transparent external layer is called **hyaloplasm.** It is really a membrane and it is very difficult to make it out as its thickness is approximately 0·0003 mm. This plasmatic membrane is an important part of the cytoplasm and plays no inconsiderable part in the process of osmosis. Whenever the protoplast is injured, the wounded surface gets covered by the plasmatic membrane and so it must be considered morphologically a part of the cytoplasm. A plasma membrane is formed

about the vacuoles also. This controls the passage of materials from and to the vacuole, just as the external membrane regulates the entrance into and from the protoplast as a whole.

As the protoplasm in every cell is completely enclosed it may be thought that there is no organic connexion of the protoplasts. It is now established beyond doubt that in the mature tissues of at least some plants there is continuity of protoplasm from cell to cell. Extremely fine filaments of protoplasm pass from the boundary layer of the protoplasm of a cell to the same layer of the protoplasm in the surrounding cells either through the entire thickness of the cell wall or through the pit-membranes. On account of these connecting filaments of protoplasm the whole of the plant body becomes an organic unit. (See fig. 183.)

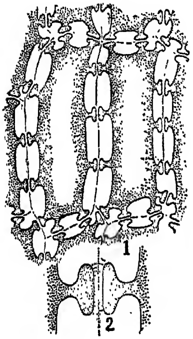


FIG. 183. Cells in the endosperm of a date seed. 1, cells with pits; 2, a pit highly magnified to show the fine filaments of protoplasm.

The nucleus.—The nucleus is a very important part of the protoplast. In embryonic cells full of protoplasm the nuclei are relatively large in proportion to the cytoplasm. Although the nucleus is centrally placed in actively growing cells, in old cells it has usually a lateral position. In the meristematic cell the nucleus may be about half the diameter of the cell, and it is spherical in shape. Older cells have smaller nuclei varying in shape.

To see the structural details of the nucleus staining is necessary. A nucleus consists of a nuclear membrane enclosing a net-work whose meshes are filled with nuclear sap. Usually a small compact body called the **nucleolus** is found imbedded in the net-work. Sometimes more than one may occur. The nuclear membrane is really a part of the cytoplasm. The reticulum consisting of colourless threads is the essential part of the nucleus. The threads do not get stained much, but some granular substance within the

threads takes a deep stain. The former are called **linin** threads and the latter substance **chromatin.**

The nucleus plays a very important part in the nutrition, growth and differentiation of the cells. When protoplasm is injured, the part in which the nucleus is found has the power to enclose itself by a cell wall, whereas the portion without the nucleus has not got this power. The process of cell division is initiated by the nucleus. The hereditary characters are transmitted only through these nuclei and hence they are the carriers of the hereditary characters of the organism. Protoplasm when deprived of its nucleus dies. The nucleus consists mostly of a highly complex substance called nuclein, and this contains phosphorus.

The Plastids.—In the embryonic cells very small highly refractive bodies are found in the cytoplasm close to the nucleus. These specialized bits of protoplasm are called **plastids** or **chromatophores.** At first they are very minute, but as cells mature they become more numerous, increase in size and in consequence they become prominent. They develop into the three kinds of plastids **chloroplasts, leucoplasts** and **chromoplasts.**

Chloroplasts.—The chlorophyll grains found in all green parts of plants are chloroplasts. In fact the green colour of plants is due to the presence of chloroplasts. They are found scattered in large numbers in the parietal portion of cytoplasm. In all higher plants these bodies are ellipsoidal or somewhat spherical, but in algae they assume various shapes. The ground substance of these plastids is a colourless matrix impregnated with a green pigment. This pigment is soluble in alcohol, and it really consists of a green pigment and an yellow one. The green one is called chlorophyll and the other, yellow one, is made up of the two substances carotin, a red pigment and xanthophyll, an yellow one. The chlorophyll grains absorb the sun's rays and manufacture carbohydrates.

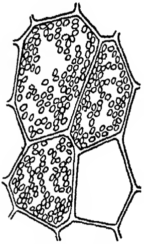


FIG. 184. Chloroplasts.

Leucoplasts are developed from the rudiments of chromatophores. They are abundant in the cells of parts of plants not usually accessible to light. They have no colour, but on exposure to light they change into chloroplasts. The transformation of sugar into starch and starch into sugar is their main function.

Chromoplasts.—The red and orange colours of fruits and flowers are in many cases due to the presence of chromoplasts. The colour is due to the pigments carotin and xanthophyll. Ordinarily chloroplasts change into chromoplasts. This is the reason why green fruits become orange or red. Chromoplasts may also arise directly from chromatophores.

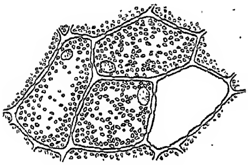


FIG. 185. Chromoplasts.

The Cell-wall.—The membrane or the cell-wall which encloses the protoplast is produced by the protoplasm. The nature of the cell-wall depends upon the kinds of cells. In the young cells of the meristem the walls are so thin that they can be seen only with difficulty, but as cells grow in length the cell-wall also must necessarily grow in extent to keep pace with the elongation of the cells. Until the cells attain their usual size the cell-wall grows only in surface and so it remains thin. This growth in extent of the cell-wall is due to the introduction of new particles between those already existing. Most of the cells do not undergo further change, but some are subjected to further development. The cell-walls become thick. Increase in thickness does not usually begin until growth in surface is nearly over. Growth in thickness is brought about by the laying down of new layers one above the other. In strongly thickened walls, such as those of the xylem and sclerenchyma three distinct layers may be made out. Inasmuch as the laying down of the thickening substance takes place on both sides of the original cell-wall, it remains in the middle of the thickened wall. This original layer often stands out clearly because it is generally more highly refractive than the other layers of the cell-wall. This layer is termed the **middle lamella.** When the thickening is very great as in

chyma, striations are clearly visible in the cell-wall on both sides of the middle lamella. The thickening of the cell-wall is never uniform. While some portions are thickened, other portions are not. Even when the thickening is considerable small areas remain without being thickened. Such unthickened spots look like small pits in surface view and as deep canals penetrating the thickness of the cell-wall in sections. These pores or pits vary in shape. They may be round, elliptical, or elongated. Further these pits in adjoining cells coincide. Sometimes these pits are branched. In sclerotic cells branching pits are very common. The pits may appear

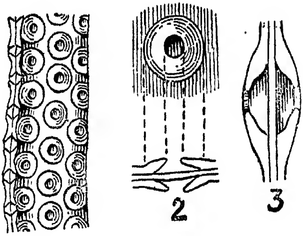


Fig. 186. Bordered pits. 1, surface view of bordered pits; 2, a single bordered pits; 3, section of a pit.

as simple ones or they may have a border around them and then they are called **bordered pits**. This curious form of pit is seen in the walls of many xylem vessels. In this form of the pit the canal, instead of having the same breadth throughout, is narrow in front and very broad towards the middle lamella. As such pits usually occur contiguously on both the sides of the cell-wall, there will be a lenticular space in the cell-wall with the unthickened portion of the cell-wall stretched across the middle of this space. In the surface view the smaller opening leading into the lenticular space appears as a small aperture and the widened border of the lenticular area is seen as a border round the small aperture. (See fig. 186.)

In some cases the thickening is very limited, the greater part of the cell remaining unthickened. When this is the case names are given according to the nature of the thickening. Vessels or cells are called **annular**, when the thickening

is in the form of isolated rings, **spiral** if the thickening is in the form of a spiral and **reticulated** if it is in the form of a network. (See fig. 52.)

So long as it is thin, the cell-wall consists mostly of the substance **cellulose**, a carbohydrate having the chemical formula $C_6H_{10}O_5$. Associated with this is found another substance called **pectin**. The thickened portions in collenchyma also consist of cellulose and pectic substance. The thickening of the cell-walls in xylem elements and in sclerenchyma is due to the impregnation of the cell-wall with various substances and to the chemical alteration of the cell-wall. This thickening is said to be **lignification**. Lignified cell-walls stain yellow with acid aniline sulphate, reddish violet with phloroglucin and hydrochloric acid and red when first treated with a one per cent aqueous solution of permanganate of potash and then with ammonia.

The thickening observed in cork cells and in the outer layers of the cells of the epidermis is due to the substance **suberin** and **cutin** respectively.

Non-living substances found in the cell or cell inclusions.—The cell being the seat of activity, many substances may be produced during metabolism. Some of these substances may be soluble, while others are insoluble. The main inclusions of the protoplasm are the cell-sap, starch grains, aleurone grains and organic or inorganic crystals and fat or oil. Besides these in the protoplasm of certain plants alkaloids, enzymes, resins and mucilage are found.

Starch grains.—The cells in the parts of plants that are green always contain starch grains. They are really manufactured by the chloroplasts and are usually very small. In seeds, rhizomes, tubers and in cells not exposed to light large starch grains are found. These grains are large because they form the reserve material. Starch grains vary in shape and they are prominently stratified. In all grains there will be a dark spot around which striations are seen. Some grains show fissures radiating from the centre. (See fig. 209.)

Aleurone grains.—These are proteid grains found in the cells of seeds, especially those containing oil. These grains are seen to the best advantage in the endosperm cells of castor seed. In this seed the aleurone grains lie imbedded in the cytoplasm and enclose albumen crystals and globoids

the latter consisting of a double phosphate of calcium and magnesium. In cereals the aleurone grains are confined to the peripheral layer of cells, and they are minute and without any inclusions.

Mineral crystals.—In the vacuoles of cells crystals are formed and these crystals finally occupy the whole of the cell. Then the cell loses all its other parts and serves merely as a store house for the crystal. It is calcium oxalate that forms the crystal. The form of the crystal is very varied. (See fig. 188.)

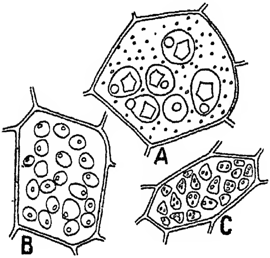


FIG.187. Aleurone grains. A, castor; B, carthamus; C, sesamum.

Sometimes they are needle shaped and occur in bundles

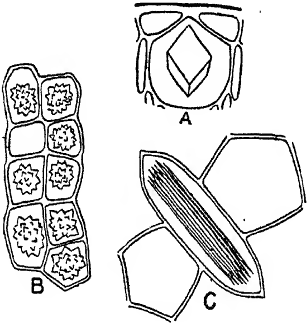


FIG. 188. Crystals of calcium oxalate. A, simple crystal; B, compound crystal; C, raphides.

and then they are called **raphides.** In some plants calcium carbonate occurs as protuberances projecting into the cell cavity. Such bodies are called **cystoliths.** They are common in the upper epidermal cells of the leaves of several species of Ficus. (See fig. 189.)

The cell-sap.—This fills the vacuoles and the meshes of the protoplasmic net-work. It is usually acid in reaction. It holds in olution soluble carbohydrates such as sugars and inulin. Occasionally it may contain anthocyanin to which is due the colours such as blue, violet, purple and red.

Form of the cell.—The young cells found in the growing points are cubical measuring on the average ·001 or ·002 m.m. These later on [illegible] cylindrical or assume various shapes. Some cells remain cylindrical or prismatic with square ends. Such cells usually retain their protoplasm and are called **parenchymatous cells.** Some of these young cells elongate very much and their ends become very pointed. Along with this change in form the cell-walls also become thick by lignification. These are called **sclerenchymatous cells** or fibres. In some plants especially those that contain a milky juice, the juice is contained in branched cells which are large and very much branched. These are laticiferous cells. They are derived from ordinary cells. Cells forming definite rows lose their transverse partitions and become continuous. By such fusions vessels are formed. The xylem vessels and the sieve tubes are formed by cell fusions and subsequently changes take place in the cell-walls. Laticiferous vessels are also formed by cell fusions.

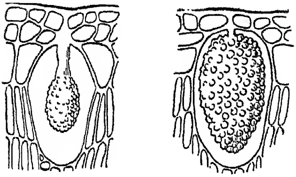


FIG. 189. Cystoliths or Crystals of calcium carbonate occurring in Ficus leaves.

Origin of the cell and cell-division.—The nucleus and the plastids found in the protoplast owe their origin to the nuclei and plastids of previous generations. Cytoplasm also is derived from pre-existing cytoplasm. None of these are formed *de novo.*

Ordinarily nuclei multiply by means of **indirect** or **mitotic** division. This process, which is also called **karyokinesis,** is a very complicated process. For the equal

distribution of the substance of a cell between two daughter cells this process is essential.

When a cell is about to divide its nucleus shows certain changes. The cell division begins in the nucleus and ends by the formation of a dividing cell-wall. The resting nucleus possesses a net-work which is delicate and diffuse. But at the commencement of the division the nuclear net work becomes coarser and gets segregated into a number of distinct bodies which ultimately become transformed into a tangle of threads. Then the threads forming the tangle separate into short stout filaments. At this stage these filaments become very conspicuous on account of the presence of chromatin discs embedded in them. These threads are called **chromosomes**. (See fig. 190—1 to 4.) Each of these chromosome threads splits longitudinally so that the number of chromosome threads is doubled. In a nucleus the number of chromosomes is always a definite number. The smallest number of chromosomes found in plant cells is three. (See fig. 190—5 to 6.)

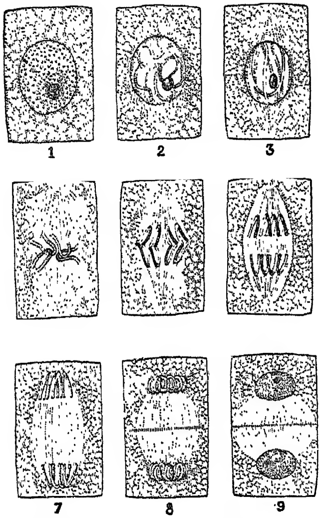


FIG. 190. A diagrammatic representation of indirect nuclear division.

While these changes are taking place in the nucleus the cytoplasm also shows some activity. The part of the cytoplasm close to the nuclear membrane gets changed into a fibrous layer which rises up from the nuclear membrane at two opposite points. The spaces thus formed between the

nuclear membrane and the cytoplasmic fibrous layer gradually increase, and in them fine cytoplasmic threads make their appearance. With the appearance of these filaments, the nuclear membrane and the nucleoli disappear. These filaments converge at two points opposite one another, one towards the top of the cell and the other towards the bottom. These two points are called **poles.** The threads proceed in a diverging manner from the poles towards the middle of the cell where a division wall appears later. (See fig. 190—2 to 6.)

After the longitudinal fission and separation into distinct segments the chromosomes usually take the form of U or L shaped rods and arrange themselves about the middle of the cell in a single plane, thus constituting an **equatorial plate.** At the equatorial plane there will be twice as many chromosomes as there are in the cell before division. (See fig. 190—4 and 5.) The chromosomes are usually connected with the cytoplasmic filaments. Some of these filaments pass straight from one pole to the other without being connected with the chromosomes at the equatorial plane. The chromosomes collected at the equatorial plane divide themselves into two halves and one portion moves towards one pole and the other portion to the other, thus forming the basis of two fresh and equivalent nuclei. As soon as the chromosomes reach the pole they become united into a net-work, nuclear membrane is formed and nucleoli also come into existence. By the time the groups of chromosomes become transformed into regular nuclei a partition wall forms in the equatorial plane and the cell becomes divided into two daughter cells. (See fig. 190—6 to 9.)

From the foregoing account of the cell division it is obvious that the parent nucleus is very exactly divided into two equal halves. There is absolutely no material change in quality of the nuclei inasmuch as an equal share of the substance of each chromosome passes to each of the new nuclei. When cells multiply in this manner, each and every cell must have exactly the characters of the parent plant. In other words each constituent nucleus will bear the full heritable qualities of the parent.

The complicated processes involved in mitotic division afford enough evidence to hold the view that the chromo-

somes are the bearers of hereditary characters. As a result of mitotic division each daughter nucleus receives an exactly similar set of chromosomes. Further these sets are exactly similar to the original one in the mother nucleus. The chromosomes are thus carefully divided and evidently perpetuated without alteration.

Reduction division.—In plants there is another kind of cell division occurring in the mother cells of pollen-grains and spores, called **reduction division** or **meiosis.** The cells of the anthers, ovules and sporangia of cryptogams undergo division in the usual manner, until the formation of the mother cells of the pollen-grains or spores. The mother cell undergoes division twice before it gives rise to the four pollen-grains or spores. During the first division the nucleus of the mother cell breaks up into chromosomes and these chromosomes arrange themselves at the equatorial plane, as they do in the case of indirect nuclear division. But the number of chromosomes in the case of the pollen or spore mother-cells will be exactly the same as the number of chromosomes in the vegetative or somatic cells, and not double the number, as is the case in ordinary indirect division of cells. If in a plant the number of chromosomes is eight in the cells, during indirect division there will be sixteen chromosomes at the equatorial plate, i.e., double the number, and each daughter cell receives eight of them. But in the division of pollen mother-cell, at the equatorial plane the number of chromosomes will be only eight and each daughter-cell will consist of only four chromosomes. After the first division, each of the daughter cells with four chromosomes again divides and forms four cells and the second division taking place is the ordinary indirect nuclear division. As the result of these two successive divisions the pollen-grains and spores contain only half the number of chromosomes found in the cells of the plant body. The reduction of the chromosomes occurs during the first division of the pollen or spore mother cells. For this reason this mode of cell division is termed **reduction division.** The cells of the plant body are called **diploid** because of the full number of the chromosomes and the pollen grains and spores **haploid** as they contain only half the number of chromosomes.

CHAPTER VIII

SYSTEMS OF TISSUES

ALL parts of plants owe their origin directly or indirectly to the cells in the growing point. By constant division cells are formed and these gradually change in their character, ultimately becoming differentiated into different groups of cells or tissues occupying definite places in the plant. The extreme tip of the growing point consists of very small cells, all alike in size and shape. But, in the cells lying below these cells, a certain amount of change becomes apparent in the size of the cells, making it possible to distinguish certain definite regions. Three distinct regions may be made out in the vegetative cones of at least some plants and they are **dermatogen, periblem and plerome.** (See figs. 191 and 192.)

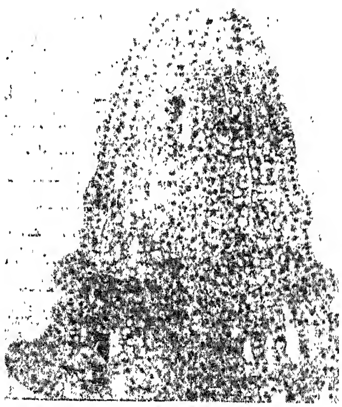


FIG. 191. Longitudinal section of the growing point of the stem of Hippuris. × 180. (From a slide prepared by Dr. M. A. Sampathkumaran of Bangalore.)

Dermatogen is the outermost layer of cells which covers both the vegetative cone and the developing leaves and buds.

The cells of this layer continue to divide only by walls at right angles to the surface. If this layer is followed downwards it will be found to be continuous with the epidermis of the stem and leaves. Therefore, we have to conclude that dermatogen is epidermis in the embryonic stage. In all plants in which the epidermis is single-layered it increases in superficial expanse to keep pace with the increase of tissues within. The epidermis being the outermost layer, it is always

FIG. 192. Longitudinal section of the growing point of the stem of Hippuris. × 450. (From a slide prepared by Dr. M. A. Sampathkumaran of Bangalore.)

distinct and its cells also look different from the cells found inside.

The central cylinder of the vegetative cone is called **plerome**, and layers of cells lying between the dermatogen and the plerome constitute the **periblem**. A clear distinction

between periblem and plerome exists only in certain plants while in others it does not exist. In some plants the distinction becomes apparent lower down. The periblem gives rise to the cortex including the endodermis, and the stele is derived from the plerome. In the plerome certain cells, a little away from the peripheral part, divide more actively and form groups of small cells. These groups of cells are called **procambial strands** or **procambium**.

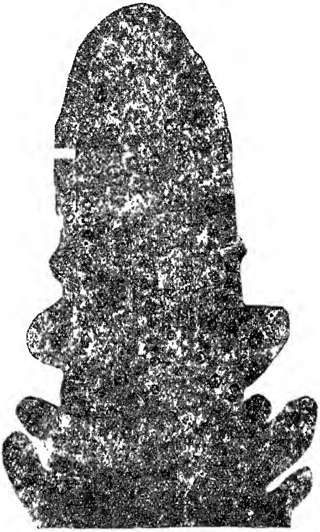


FIG. 193. Longitudinal section of the growing point of Elodea stem very highly magnified. (From a slide prepared by Dr. W. Dudgeon of Allahabad.)

In most dicotyledonous stems these procambial strands occur as isolated strands arranged in the form of a ring. Subsequently vascular bundles arise from these strands. All the parts of the stele, namely, the pericycle, the vascular bundles, the pith and the medullary rays, are derived from the plerome.

Meristem.—The aggregate of actively dividing cells in the apical portion of the vegetative cones of stems and roots of plants constitutes a kind of tissue on account of their

similarity in structure and function. All these cells have approximately the same form and structure, and are characterized by their relatively small size and large nuclei. (See figs. 191 to 193.) The apical meristem is continually carried forward by the enlargement of the cells beneath it that have been formed by its own activity, just as a man standing on a brick-wall which he is constructing is pushed upwards with each successive layer of bricks. The meristem found at the apices of growing points of all the branches of a plant owe their origin to the meristem of the growing point of the seedling of the plant.

Besides the vegetative cone there are other parts also in a plant in which this tissue is found. The cambium which is the cause of secondary thickening in stems and roots and the cork-cambium come under this head. But this meristem differs from the meristem of the vegetative cones in one important respect. While the apical meristem of the vegetative cone is derived directly from pre-existing meristem, the cambium ring and the cork cambium are formed from parenchymatous cells which have ceased to divide and hence not meristematic. On account of this difference cambium and cork-cambium must be termed secondary meristem, reserving the term primary meristem to that meristem which persists as such, throughout its life and which was present as such, at the first origin of the member.

All cells and tissues that have ceased to grow constitute permanent tissue. All tissues other than meristem come under this category.

Epidermis.—The epidermis is the membrane or the outer layer of cells covering the stem, leaves and roots of a plant. This tissue is formed from the dermatogen. In the vast majority of higher plants the epidermis consists of only one layer of cells, and the cells are always more or less flattened or tabular. These cells vary a great deal in different plants and habitats and in different parts of

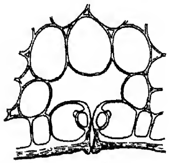


FIG. 194. Epidermis and Stoma of Aloe leaf. Note the thick cuticle on the epidermis.

the same plant. The epidermal cells of most dicotyls are nearly isodiametric, while in monocotyls they usually are elongated in the same direction as is the leaf.

In typically developed epidermis the outer walls of the cells are usually thickened, and this thickening becomes more pronounced in plants which live in dry places or bright sunlight. While the epidermal cells that are young are undergoing changes in size, the outer wall, as a rule, becomes thicker and chemically altered. The chemical alteration consists in the addition and infiltration of a substance called cutin. The cutinisation and thickening occur only in the outer walls, and the side walls remain thin. In addition to the thickening of the external wall, cutin becomes deposited on it almost in a pure state, so as to form a continuous layer over the whole surface of the epidermis. This continuous layer overlying the epidermis is called **cuticle** and this is very prominent in xerophytes, such as Agaves and Aloes. (See fig. 194.)

In some plants wax may be found deposited on the cutinised layers of the epidermis. The so-called bloom on stems, leaves, and fruits is due to the deposit of wax. Occasionally the walls of epidermal cells are infiltrated with silica, as in some Gramineæ.

The epidermal cells are in uninterrupted contact with each other, the continuity being interrupted only here and there where stomata occur. So long as these cells are alive, they contain protoplasm which is generally reduced to a very thin layer with the sap cavity filled with either colourless or coloured cell-sap. The epidermal cells do not generally contain chloroplasts except in the guard cells of the stomata, although chloroplasts may occur in rare instances. Although the colourless rudiments of chromatophores exist in the protoplasts of epidermal cells, they do not develop into chloroplasts. Therefore we have to infer that epidermal cells are not destined to take part in the process of photosynthesis. Very often the epidermal cells serve as water-reservoirs, inasmuch as their lateral walls are thin and are capable of adaptation to the variations in the supply of water.

The epidermis on account of the thickening and cutinisation of the external wall forms an excellent protective tissue

against loss of water, parasitic fungus and mechanical injury. The epidermis is the only protective tissue existing in herbaceous plants and in herbaceous parts of perennial plants. Further it is the first, and often the only, protective tissue that is formed in plants. Its chief value lies in the protection against a too rapid evaporation of water. This function of the epidermis will be considered later in connexion with the work of the foliage leaves.

In spite of the cutinisation and thickening of the outer wall of the epidermis, comparatively speaking it is to be considered only thin. Therefore, it may be thought ill adapted to withstand mechanical injury. But considering the fact that the epidermal cells are small and that the radial walls are very numerous and close, any mechanical impact will be borne by the radial walls very effectively. Furthermore, the outer wall of the epidermal cells generally curves outward and this also is advantageous. When the outer wall is silicified the walls become more resistant.

Although the epidermis is single-layered in typical cases, it is many layered in some plants, such as Ficuses and Nerium. In these cases the extra layers serve as very efficient reservoirs for water.

The epidermis very often bears on its surface outgrowths of various kinds. The simplest outgrowth is the hair, which is merely a prolongation of the outer wall of the epidermis. In young buds of some plants numerous long hairs form a more or less thick coating, which protects the buds against a too rapid evaporation of water. Some plants have glandular hairs, others branched or stellate hairs. Occasionally the hairs get infiltrated with carbonate of lime or silica and become stiff bristles. Stinging hairs and scales also occur in the epidermis of some plants. In some plants prickles are found but they are not derived solely from the epidermis. A portion of the sub-epidermal tissue also takes part in their formation.

The stomata are found in large numbers on the green parts of plants and especially in the leaves. Generally the lower epidermis of leaves contains the largest number of stomata. Some leaves have them on only one side and in others both the sides may have them. In a square millimeter

of space stomata average from 100 to 300. As examples of leaves having stomata on both sides we may mention *Cucurbita pepo* and grasses. The lower epidermis of the leaves in Cucurbita have about 270 stomata in a square millimeter, and on the upper epidermis they average about 28 to a square millimeter. In the leaves of grasses both the sides contain very nearly the same number of stomata. At any rate, there is not very great difference. In the leaf of Zea the lower surface has 68 per square millimeter and the upper 52. The stomata are mainly useful in the matter of exchange of gases.

Periderm or **cork tissue**.—Considering the nature of epidermis it cannot be expected to become a permanent protective membrane, although it is known to persist for a number of years in some species of Viscum and Acer. Sooner or later it is replaced by cork, which is formed in the cells of the cortex either superficially or deeply. In roots cork is derived from the pericycle.

When fully developed the periderm consists of rows of cells forming closely packed tiers without intercellular spaces. The cell walls are usually thin but suberised, rendering them impervious to both air and moisture. As cork tissue is many layered it is more efficient as a protective membrane than epidermis, both against loss of water and mechanical injury. Air being a bad conductor, the cork tissue which consists of cells with plenty of air in them protects the inner tissues against injuries that might result from sudden changes in temperature.

Cork begins to form only after a certain amount of secondary thickening has taken place. The appearance of brown colour in stems is an indication of the formation of cork. The periderm arises from a secondary meristem formed in the parenchymatous layers of the cortex. This is called **phellogen** or **cork combium**. Some of the parenchymatous cells begin to divide and then phellogen is established. As a rule phellogen is a cambium with a persisting initial layer, from which cork cells arise outside. In some plants this initial layer gives rise to new cells inside also, thus adding to the cortex some more layers of cells. These new layers form the **phelloderm** or secondary cortex.

Lenticels.—The cork tissue is a continuous layer, except where lenticels occur. **Lenticels** or cortical pores are formed simultaneously with the cork tissue. On stems lenticels appear as slightly swollen round, oval or narrowly elliptical spots or excrescences, and when seen under a lens a lenticel is seen to be a narrow slit filled in with some powdery tissue.

Like cork, lenticels also are formed from phellogen. They almost always develop directly under the stomata. The cells formed in the case of a lenticel do not at all resemble the cork cells. The cells of lenticels are more or less rounded and lie loosely with intercellular spaces. In fact a lenticel is nothing but a group of loose cells. As new cells are formed regularly from the phellogen at the bases of the lenticels, they remain for years and may grow to a large size. Besides the loose cells, there are also found sometimes intermediate bands, shutting off the loose cells from the layers below. These closing layers also ultimately get ruptured. The cell walls of the loose cells are not usually suberised, although the cells of the closing bands are suberised or lignified. The phellogen of the cork and that of the lenticels join laterally and become continuous.

Lenticels are obviously intended to facilitate the ingress and egress of gases. How this is rendered possible will be explained later.

Mechanical tissues.—The ærial parts of plants, especially stems, need a certain amount of strengthening tissue to enable them to withstand the strain caused by winds and weight. Very young parts consisting of young cells, which are usually firm on account of turgidy, need no special strengthening tissue. But as differentiation of cells sets in, other kinds of strengthening tissues begin to be formed. The chief mechanical tissues are **collenchyma, sclerenchyma, sclerotic cells** and **wood fibres.**

Collenchyma.—The first mechanical tissue that is formed in a stem is collenchyma. Whilst the vascular bundles and fibres are forming inside, collenchyma makes its appearance beneath the epidermis. At first it consists of a few layers, but it goes on increasing with the growth of the stem. This is always found peripherally beneath the epidermis and

it does not occur in any other place. It forms a continuous layer in some cases, and in others it exists as isolated strands.

The special characteristic of collenchymatous tissue is that it consists of living cells whose walls are greatly thickened, especially at the corners where the cells meet. Sometimes the thickening is so great as to completely obliterate the

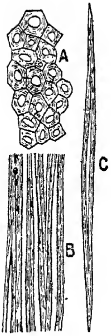


FIG. 195. Sclerenchyma. A, Transverse section; B, longitudinal section; C, a full fibre in longitudinal section.

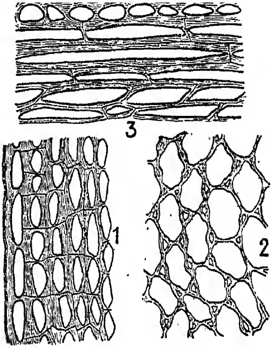


FIG. 196. Collenchyma. 1 and 2, Transverse sections; 3, longitudinal section.

cavity. The thickening is entirely due to cellulose. Collenchyma owes its origin to the parenchymatous cells of the cortex.

The chief function of collenchyma is to give strength to parts of the stem still growing. The great thickening of the cells affords the necessary strength, whilst the living contents enable the cells to grow and keep pace with the increase of the tissues within.

Sclerenchyma.—This tissue is specially intended to give strength to parts that have ceased to grow in length. It is ound in the stem either as a continuous layer, or as isolated strands. In the cortex of several plants sclerenchymatous bundles may be seen forming regular net-works. It is not unusual to find them alternating with phloëm masses. Very often portions of the pericycle change into fibres. In the

xylem isolated fibres are found mixed with the other elements of xylem.

The vertical elongation, lignification of the walls, the tapering ends and the very close interlacing to form bundles so characteristic of fibres make them not only strong but also elastic. The main use of sclerenchyma is to afford sufficient strength to the members in which it occurs. Besides giving mechanical strength, sclerenchyma is intended to protect soft and delicate tissues such as phloëm.

Sclerotic cells or stone cells result when cells undergo thickening without elongating very much. These are characterised by very great thickening, appearing as distinct striations and by the possession of very conspicuous branched pits. (See fig. 197.) They occur in the cortex, pericycle and the pith, either singly or in masses. In the hard parts of fruits and seeds they are abundant. In fact the hard part consists of stone cells.

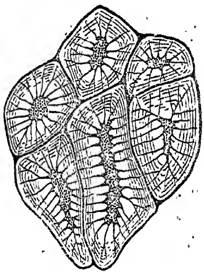


FIG. 197. Stone cells.

Wood fibres.—The sclerenchymatous fibres occurring in the xylem, though similar to the ordinary fibres occurring as bundles, are very much shorter in length and their function is to bind and connect the other elements of the xylem. The character of the wood is affected by the proportion of the amount of fibre present in it.

Vascular tissue and vascular bundles.—As already stated, a typical vascular bundle of a dicotyledonous stem consists of the three parts, **xylem, phloëm** and the **cambium**. All these three parts in a primary vascular bundle are derived from the procambial strands. In a procambial strand the inner portion becomes differentiated into xylem and the outer portion into the phloëm, while a small portion lying between these two parts remains unchanged in the dicotyledonous stem. This layer persisting in the primary vascular bundle continues to be meristematic and hence it is called a cambium. As it is within the vascular bundle, it is called

fascicular cambium. Vascular bundles with cambium are termed **open vascular bundles.**

The xylem portion consists of vessels or trachea, wood parenchyma and fibres. A vessel is formed by the fusion of a vertical row of cells. The transverse walls are completely absorbed and the cell walls become variously thickened. Vessels are named according to the nature of the thickening, and we have already spoken about the different kinds of vessels (see page 47). These vessels or trachea are introduced to carry water from the roots to the leaves.

The wood parenchyma cells have usually thickened walls, pitted or not. These cells are mainly useful in the storage of water and reserve food materials. The cells of the medullary rays of the xylem are parenchymatous cells with lignified walls.

The phloëm portion of a vascular bundle is an assemblage of sieve tubes with companion cells and phloëm parenchyma. Sieve tubes are thin-walled vessels with perforated transverse plates or sieves, and they are always associated with companion cells, at least in Angiosperms. The parenchymatous cells are usually small cells, with thin walls.

The sieve tubes contain protoplasm when they are young, but without nuclei. The contents of the active living sieve tubes consist of proteids, amides, minute starch grains and carbohydrates. The sieve tubes are the channels for the translocation of proteids and allied substances.

The parenchymatous cells of the phloëm are usually small and seem to be useful in the translocation of carbohydrates and also for the storage of proteids and other substances. Phloëm remains in an active condition for one year usually, although it may continue its activity for a longer period in some plants.

In monocotyledonous stems the procambial strands become differentiated into xylem and phloëm without any part of it persisting as cambium. The whole of the procambial strand is used up and these bundles are called **closed vascular bundles.** (See fig. 198.) The open bundles of the dicotyledonous stems are called **collateral vascular bundles** (see fig. 199) because the xylem and phloem are on the same radius one behind the other. In some stems phloëm occurs

on both the sides of the xylem and such bundles are called **bicollateral vascular bundles.** (See fig. 200.) In the roots of both monocotyledonous and dicotyledonous plants the

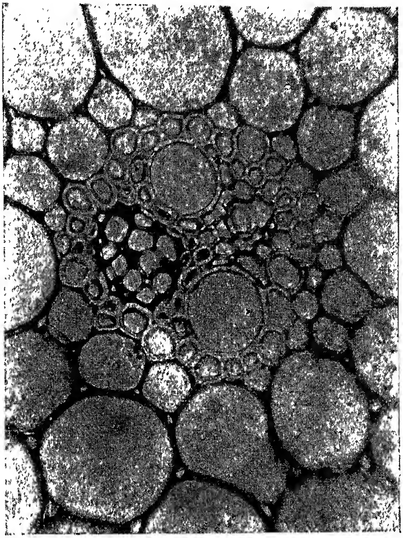


FIG. 198. A closed vascular bundle.

xylem and the phloëm lie side by side on different radii in the primary vascular bundles. These bundles are called **radial vascular** bundles. All vascular bundles end in the leaves. These descend into the stem from each leaf, and after traversing one or more internodes they branch and fuse with the bundles that enter the stem at the lower nodes. So all the vascular bundles of the stem are continuous. The vascular bundles descending into the stem from a leaf form the leaf trace bundles. All the vascular bundles disposed in the form of a ring in the stems of dicotyledonous plants are composed of leaf trace bundles. As the bundles are common to both the stem and the leaf, they are called common bundles. The upper part of the bundle which runs through the cortex

towards the leaf is termed leaf-trace. Within the stem the vascular bundles run parallel to the epidermis through the internodes, but at the nodes there is a considerable amount of branching and intercommunication of these bundles.

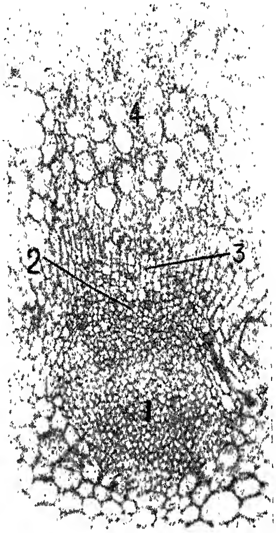


FIG. 199. A collateral vascular bundle. 1, sclerenchyma (pericycle); 2, phloëm; 3, cambium; 4, xylem.

Parenchyma.—The great bulk of the cells found in the cortex, pith of stems and in the leaves constitutes parenchyma. The cells of parenchyma are all living cells and vary in shape. The cell-walls consist mostly of cellulose. As the cells of this tissue contain protoplasm they serve various purposes. They carry on the work of storage of food materials, assimilation and nutrition. They also contribute towards mechanical strength by their turgidity.

Laticiferous tissues.—In the stems and leaves of many plants milky juice abounds, as in Euphorbia, Ficus and Lactuca. This milky juice or latex is usually contained in branched cells or in branching and anastomosing vessels.

The latex tubes in Euphorbia, in Asclepiads and Apocynads are cells developed into branched tubes. These tubes only

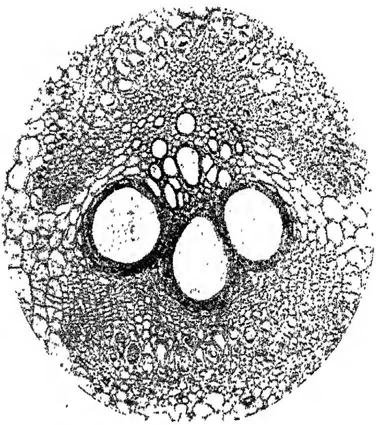


FIG. 200. A bicollateral vascular bundle.

branch but they do not anastomose. On the other hand the latex vessels in Lactuca and Argemone are vessels and are formed

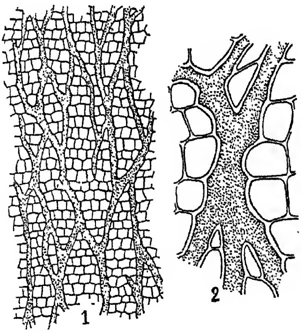


FIG. 201. Laticiferous system. 1, slightly magnified; 2, highly magnified.

by fusion of cells. These always anastomose and form networks. (See fig. 201.)

Latex is usually a white milky juice, and it is occasionally watery or yellowish. This liquid contains gums, resins, caoutchouc, fat and wax in emulsion. In some plants enzymes and poisonous alkaloids, are also found in the latex. As these substances are of the nature of excreted products, the tubes are often to be regarded as reservoirs of excreted substances. However, occasionally, starch grains and proteid grains occur in the latex. In such cases it is probable that latex tubes serve for storage and transport of nutritive material.

Glandular tissue.—This tissue varies very much in its structure. The glandular hairs occurring as outgrowths of the epidermis are of the simplest kind. The terminal cell of such hairs usually functions as a gland. But cells, other than the terminal one, may also secrete.

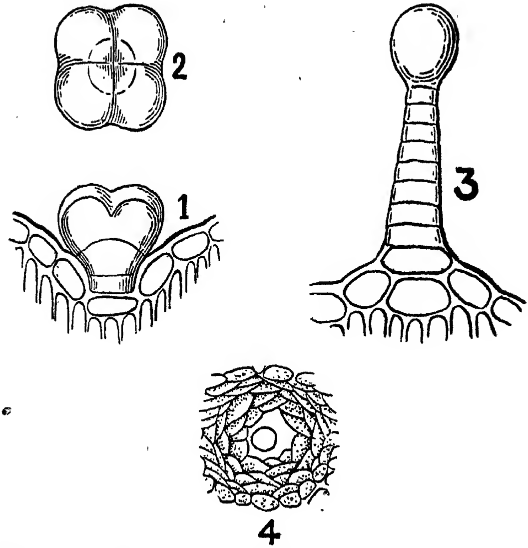


FIG. 202. Glandular hair and oil glands. 1, side view and 2, top-view of a glandular hair of *Ocimum Basilicum*; 3, glandular hair of Petunia; 4, oil gland of Citrus.

Sometimes a group of cells of the epidermis and sub-epidermal tissue secrete honey, thus forming a nectary. Generally nectaries are met with in the parts of flowers.

There are also cavities or passages formed in various parts of plants in which, ethereal oils, gums and resins are secreted. The oil glands seen in the leaves and in the rind of the fruits of the lime and orange trees are really cavities formed by the destruction of some of the cells. Such cavities are termed **lysigenous** cavities. Resin ducts or passages also occur in plants and these are formed by the

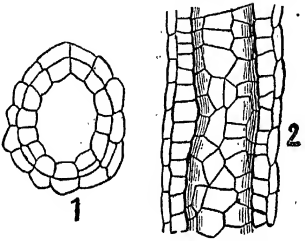


FIG. 203. Resin ducts. 1, transverse section; 2, longitudinal section.

separation of cells first so as to form a slit in the intercellular space and then by further separation it becomes wider. **Resin ducts** occur in the cortex in the stem of Helianthus. Such passages as these are called **schizogenous** cavities or passages.

CHAPTER IX

THE WORK OF THE VEGETATIVE ORGANS OF A PLANT

As a plant is a living organism we should expect its life to be similar to that of an animal in all essential respects. Like animals plants also have to eat, and without food they cannot live. We know, from the study of seedlings, that a young plant gets its food from the cotyledons or the endosperm. But very soon this source of supply fails, and it is forced to obtain food from other sources.

A very young plant still in the course of development does not show the characteristic features of vegetable life, until it begins to lead an independent life, i.e., until the roots penetrate the soil so as to get a firm hold, and the shoot stretches into the air towards the light. A plant is capable of living independently, as soon as foliage leaves are formed.

When we recall to our mind the main structural features of a flowering plant, it at once becomes obvious that all the food materials that a plant needs must get into the interior of the plant body, either as a liquid, or as a gas. Further, it must obtain everything it wants, either from the atmosphere, or from the soil. It is evident that substances in the soil needed for the plant have to get into the plant body only through the roots.

For a clear understanding of the kinds of substances absorbed by the root from the soil, and the manner of absorption, we should learn something about the soil.

Soils in which plants grow usually consist of two substances : (1) humus or organic matter resulting from the decomposition of plants and animals, and (2) mineral matter chiefly consisting of sand and clay in various proportions. Humus gives to the soil a loose open texture and it is capable of retaining a very large amount of water, besides containing plenty of plant food.

In most soils we find sand, clay and humus ; but these vary in their relative proportions in different places. A soil

is said to be sandy, if the proportion of sand is high; and such a soil is more open, more porous, warmer and drier than clay soils. A pure sandy soil is of no use to a plant, for practically it contains nothing that is likely to be of use to the plant. A soil containing a large amount of clay with a very small quantity of sand is called a clay soil. And this soil tends to form a hard compact mass and so the roots of plants cannot penetrate it. When wetted it becomes sticky in texture, impervious to water and impenetrable to the roots of a plant. It is possible, by a proper admixture of humus, clay and sand, to obtain soils of any desired consistency or texture, and also of any grade of fertility.

Soils may be classified as follows :—

Sandy soil	... ...	80 to 100 per cent sand.
Sandy loam	... ...	50 to 80 ,, ,,
Loam	... ...	40 to 50 ,, ,,
Clay loam	... ...	20 to 40 ,, ,,
Clay	... ...	0 to 20 ,, ,,

A soil which is good for growing plants will contain a certain amount of water; and this water will generally exist as isolated drops held by the soil particles between them and it may also remain as thin films adhering to the soil particles. The remaining space is filled with air. (See fig. 51.) For the proper development and growth of the root-systems of land plants, this air is absolutely necessary. When the soil is water-logged through lack of drainage, this air is excluded and the root-systems of these plants suffer very much.

The work of the root.—In the embryo plant which is just trying to come out of the seed, the part which develops first is the root. It is so, as the plant needs water for growth, and water is available only in the soil, and therefore, the roots of plants find their way into the soil. Thus from the very commencement roots have not only to take on themselves the work of absorbing water from the soil, but they have also to fix the plant in the soil. We must now try to learn how a root absorbs water and which part of it is actually concerned in this work.

Absorption of water is an essential feature of a living cell. Plants of low organization and submerged aquatics

absorb water through the entire surface of their bodies. In land plants this work is restricted to the young parts of roots, and the root-hairs.

In the ordinary soil, water exists as fine films firmly held by the surface forces of the particles of the soil. For absorbing the water, thus existing in the soil, in sufficient quantities and as quickly as possible to meet the demands of the plant, roots must have a large amount of surface. From the free branching of the roots a certain amount of increase in surface results. By the formation of the root hairs there is a further increase of the surface for absorption. In a root of *Zea Mays* about 1/17 inch in thickness 450 root- hairs were found in ·01 square inch of space. The root-tip of a Pea plant was found to have 230 root-hairs in a square millimeter of space. The root-hairs grow at their tips and get into the air spaces. When a root-hair comes in contact with a soil particle it stops growing in length, then bends and flattens itself firmly over the particle. The very delicate cell-wall just where it comes in contact with the soil particle becomes mucilaginous. Thus it is obvious that the root-hairs not only tend to increase the surface for absorption but also bring about a very close contact with the soil and soil water.

A root-hair is merely a living cell very much elongated. Like an ordinary cell it consists of a cellulose membrane enclosing a vacuolated protoplasm. We know that protoplasm will be active only when there is water. And so it should have an inherent capacity to absorb water.

The process of absorption really consists of three distinct processes, viz., imbibition, osmosis and protoplasmic absorption.

The cell-wall of the root-hair is highly hygroscopic and consequently it adheres very firmly to the soil particles. The film of water round the soil particles gets into the cell membrane by overcoming the cohesion of the molecules of the cell-wall. The cell-wall swells and even becomes mucilaginous as a result of this entrance of water into it. Water enters the protoplasm also, and thus makes both the cell-wall and the protoplasm more porous. This is obvious because there is swelling. All these are included under the term **imbibition.**

By mere imbibition the process of absorption cannot go on continuously. There must be some other force at work to ensure continued absorption of water. It is a well-known fact that when two fluids or solutions of unequal density are close tegether and only separated by a porous membrane, the fluids or the solutions will get through the membrane and mix with each other. At first the weaker solution will flow towards the membrane and get into the stronger solution, and later on the stronger solution will diffuse through the wall into the dilute solution. This double diffusion through the membrane will go on until the density is the same on both the sides. This process of diffusion is usually spoken of as **osmosis**. The diffusion into the denser liquid is termed **endosmosis**, and that in the reverse direction is called **exosmosis**.

A close observation of the behaviour of cells containing coloured cell-sap, such as those of the staminal hairs of Cyanotis, or of petals or of the rind of fruits, when laid in water and in salt solution will convince us that water is absorbed by cells. Such cells when mounted in pure water show under the microscope the cell-wall, the cell-sap inside the cell and a thin layer of protoplasm in close contact with the cell-wall. On replacing the water by an aqueous solution of potassium nitrate of about 10 per cent strength a remarkable change takes place in the cells. The protoplasm instead of remaining close to the cell-wall shrinks away from it, leaving a wide space between itself and the cell-wall. Within the protoplast there will be the coloured cell-sap, now diminished in quantity. This shrinkage of the protoplasm caused by the strong salt solution is called **plasmolysis** and the cell is said to be **plasmolysed.** On removing the salt solution and introducing pure water the protoplast regains its original condition. When cells are placed in potassium nitrate solution the solution passes through the cell-wall freely, but the layer of protoplasm, instead of letting the solution to pass through it into the vacuole, it allows a certain amount of water to pass through it to the outside to mix with the solution, and this is why it shrinks. As the colour is confined to the cell-sap within the protoplast even after plasmolysis, it is obvious that the pigments to which the

colour is due do not pass through the protoplasmic layer although water has passed out. In other words, while the cell-wall is permeable to both water and the substances dissolved in it, the protoplasmic layer is not so permeable. So long as the cell is living the protoplasmic layer will be only semipermeable, i.e., permeable to certain substances but not to others. This guardianship of allowing only certain substances and water to pass through the protoplasmic layer is held to be the function of the outer hyaline protoplasmic membrane, hyaloplasm.

This semi-permeability is not confined to protoplasm. There are also other non-living membranes especially those of a colloidal nature that are semi-permeable. For example, the precipitation membrane formed when two solutions are brought in contact and collodion membranes are of this nature. If a membrane of collodion be tied to the mouth of a thistle funnel tube, filled with water containing a small quantity of tannin and lowered into a beaker of glass containing a weak solution of iron sulphate, the clear solution within the thistle tube gradually becomes black whilst the liquid in the beaker remains quite clear. On reversing the arrangement the water outside becomes black, but not the water in the thistle tube. Thus it is clear that tannin does not pass through the membrane, but only water and iron salt do so. The precipitation membrane formed when copper sulphate solution comes in contact with potassium ferrocyanide is permeable to water but not to either copper sulphate or potassium ferrocyanide. If a drop of a strong solution of copper sulphate solution is allowed to come in contact with a weak solution (3 per cent) of potassium ferrocyanide in a beaker through a fine tube, a membrane is at once formed at the end of the fine tube, which will burst due to entrance of water into the copper sulphate solution from the beaker. Once again a membrane will be formed which would again and again swell and burst due to pressure caused by entrance of water.

A root-hair is a membranous bag filled with water in which various substances are dissolved. The film of water adhering to the soil particles is a weaker solution compared with the water inside the cell-wall. And according to the physical

laws of osmosis, water in the soil will flow into the root-hair through the cell-wall. The porous wall will also be wetted by the cell-sap from inside, and the cell-sap being denser will tend to diffuse into the soil if we assume the protoplasm also to be as permeable as the cell-wall. If this goes on continuously there will be no absorption of water into the plant. But in the root-hair we have a semipermeable membrane with soil water containing easily diffusible salts in very small quantities on one side and the cell-sap consisting of water and organic substances which are colloidal, and hence not capable of diffusion, on the other. The protoplasmic layer is permeable only to water in the cell-sap but not to several substances in it. The soil water is a weak solution compared with the cell-sap. Therefore, soil water must of necessity get into the root-hair. As protoplasm is living and active there will always be highly osmotic substances in the cell-sap.

The ordinary process of osmosis is thus modified in the root-hair of a plant, in such a manner that water will pass freely into the root-hair, but the diffusion of the cell-sap from the root-hair into the soil is rendered difficult, if not impossible. The protoplasm lining the wall of the root-hair allows endosmosis to go on, as it has a great affinity for water. But the current in the reverse direction (exosmosis) will be extremely slow. Generally the cell-sap flowing outwards is very small in quantity and is acid in reaction. This acid reaction is due to the presence of carbonic acid. The roots of land plants, according to the researches of scientists, do not seem to excrete any free acid except carbonic acid. The solvent action of the root is entirely due to the action of the carbonic acid.

The protoplasm of the root-hairs, in addition to the power of modifying the ordinary process of osmosis, may be said to have the power of selection as well. Water is very rarely absorbed as it exists in the soil. The protoplasm has not got the same affinity for both water and salts. It has a greater attraction for molecules of water when there is more salt, and will take in more salt when the water is dilute. This selective power of protoplasm in the root-hair, by which it takes up water and soluble salts without strict regard to their proportion, is of very great importance to the plant.

The flow of water from the root-hair into the adjoining parenchyma of the cortex is in accordance with the ordinary laws of osmosis. From the cortex water gets into the vascular bundles.

Soon after absorption of water, a cell becomes turgid and the internal pressure becomes greater. All the parenchymatous cells of the cortex of the root become turgid. The pressure in all these cells increases and this pressure is called the root-pressure.

In this connexion the endodermis is believed to be of great use to the root in preventing water from passing laterally outwards. This layer is well developed in the root and on account of the thickening of its lateral and inner walls, which is due to suberisation, it is impervious to water. In younger stages some of the cells of the endodermis do not undergo thickening, as they are meant to facilitate the passage of water from the cortex into the vascular bundles. As roots get older these cells also disappear and all the cells of the endodermis possess the thickening.

In several plants the root-systems have other functions besides the normal function. For instance in *Ipomœa Batatas* the roots swell and begin to store starch. As other examples we may mention the roots of Radish, Carrots, etc. Sometimes roots help the plants in clinging to supports.

Roots of land plants possess the power of reacting to the external conditions and accommodating themselves to them. Their growth and development depend upon many conditions. The amount of water in the soil, its quality and concentration, amount and character of the food material, the temperature of the soil and its aeration are the factors that influence the development of roots. Roots are always highly sensitive to moisture, and this is expressed by saying that roots are hydrotropic. Young roots have always a tendency to go towards places where there is water, even overcoming geotropic tendencies, if necessary.

The power of adaptation possessed by the roots is of great use to the life of the plant. Typical land plants have roots that are capable of normal growth even when the medium of the root-system is changed from soil to water. Hence water culture experiments are possible.

The formation of the root-hairs should also be considered, as they are the organs directly concerned in the work of absorption. A dry soil is not favourable for the development of root-hairs; but in an atmosphere saturated with water vapour the development of root-hairs is most marked. Soil conditions most unfavourable for the development of root-hairs are lack of moisture, resistance of anything that is hard and too high a concentration of the water in the soil.

The development of the root-system as regards its shape and position depends also upon the kind of the plant, provided that the root-system is adapted to the external conditions as far as it is possible. For instance, the roots of a Cholam plant springing from the seed sown in the soil at the usual depth, as well as those of the same plant arising from seeds sown somewhat deep develop in the same layer of the soil. If the rhizomes of Canna or Curcuma are planted very deep, the new branches arising from the deep rhizomes are all directed upwards until they attain the normal depth of the soil.

The work of the stem.—The stem grows above the ground and so its medium is air. Just as the root-system absorbs water from the soil the shoot-system takes in something from the air. Evidently the materials absorbed by the shoot-system must be quite different from those absorbed by the roots. The root-system should have a large amount of surface for absorption, and it is the root-hairs that bring about this increase. The shoot-system bears as appendages leaves, and they are the parts that take in substances from the air. So the leaf surface is the most important part of the shoot. In all land plants there are two surfaces, the root-surface and the leaf-surface. These two surfaces must be in constant intercourse. And these two surfaces are connected by the stem.

In all ordinary plants the leaf-surface and the root-surface have the stem between them. But this intermediary organ, the stem, is not a very essential organ to the plant, in the same way that the leaves and roots are. We have instances of plants having stems that are poorly developed, as in Crepis, Taraxacum, or the Radish. In all these plants the leaves lie almost flat upon the ground,

The water absorbed by the root-system gets into the xylem of the root and, as this is continuous with the xylem of the stem, it passes into the stem. The vascular bundles of the stem are prolonged as veins into all parts of the leaves. They may be compared to a series of pipes, serving to collect the water absorbed by the root, to carry it with relatively slight loss through the stem and to distribute it to all parts of the leaf. Thus transport of water is one of the duties of the stem.

That water is transported in the stem and the leaf, only through the xylem, can very easily be demonstrated by a simple experiment. Place a fairly well developed seedling of any plant in water, coloured red with eosin, and after an hour or two examine transverse sections cut through the stem and root. In the stem the xylem alone will be red, whereas in the root all the parts, root-hairs, the cortex and the xylem will be stained red.

Considering the fact that considerable amount of water is passing through the xylem which is nearer to the periphery than to the centre, it is obvious that it should be properly protected against evaporation. In all young stems the epidermis affords enough protection and in the roots the endodermis and the exodermis are useful in this direction. But in older stems and roots, in which secondary thickening is going on, a more effective membrane is required. So we find in these periderm or cork tissue taking the place of the epidermis. Besides forming a very efficient water-proof covering, cork also affords protection against the bad effects that may result when sudden changes of temperature occur, because it is a very bad conductor. The importance of cork as a water-proofing material can be realized by the fact that a potato deprived of its cork covering loses in two days sixty times as much water as an unpeeled one of equal weight.

It must not be forgotten that the stem has to support leaves, buds, flowers and fruits besides being the channel for the conveyance of water.

The upward movement of water through the xylem cannot be due to osmosis, because the xylem elements have all thick walls. But instead, imbibition and infiltration are possible. The chief cause of this upward movement of water

is still an enigma, as none of the explanations so far advanced are satisfactory. Root-pressure, capillarity, evaporation from the leaf surface and osmotic pressure are undoubtedly the probable causes. Of these the most important factor is the evaporation of water from the leaves. When a cell loses water by evaporation, the loss will immediately be made good by the passage of water into this cell from the neighbouring cell. This second cell will affect the third cell and this in its turn the fourth and so on. The loss of water from a cell by evaporation makes the cell-sap denser and this leads to an increase in the osmotic pressure of the leaf cells. The effects of transpiration will be felt by all the cells from the root upwards. In conclusion, we may safely consider transpiration to be one of the chief factors concerned in lifting the water up the stem.

The work of the foliage leaves.—The part played by the leaf and its importance to the life of the plant was not known, until the end of the eighteenth century. Before that period

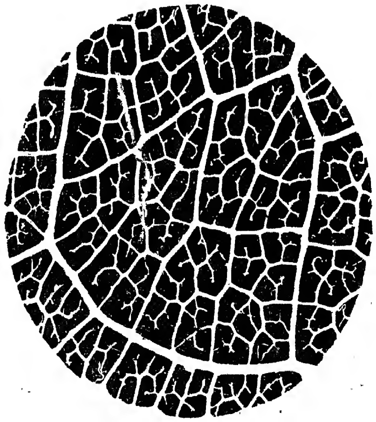


FIG. 204. Net-work of veins.

the leaf was considered to be a useless organ. But now we know that the leaf is as important an organ as the root, nay

even more important. It is the leaf that prepares for the plant its chief food. So an eminent botanist says that "the leaf embodies the very essence of a plant life."

To understand the work of the leaf it is necessary to recall to our mind the main features of its structure. The mass of parenchymatous cells forming the bulk of the leaf are held together and kept in position, by the network of veins, and covered over on both the sides by the epidermis. Stomata are most abundant in the lower epidermis. They are either fewer in the upper epidermis or they are absent. There are air cavities immediately below the stomata.

The foliage leaf is an organ specially adapted for the reception of light and absorption of gases. It is also the chief place for the loss of water by evaporation.

Of all the organs of the plant, it is the leaf that needs water in large quantities. The water absorbed by the root reaches the veins of the leaf, and from there it passes to the parenchymatous cells.

The fine net-work of veins besides forming a very efficient frame work to keep in position the mesophyll cells of the leaf is also useful in carrying water to every nook and corner of the leaf, so that all the cells of the mesophyll may draw water. Further the cells of the bundle sheaths bordering the veins take in the water from the veins very readily to deliver them to the palisade and spongy parenchyma. They are also useful in helping the transfer of food from parenchyma to the sieve tubes.

The thinness, flatness, the horizontal position and the arrangement of the parenchyma are favourable conditions for the evaporation of water from the leaves. However, evaporation does not seem to take place all through the surface of the leaf, because the epidermal cells are cutinised on the free surface. The actual transpiring surface is the surface of the cells bordering on air spaces both in palisade and spongy parenchyma. Water escapes into these air spaces and then this gets out through the stomatal openings into the air. This escape of water as vapour leads to the concentration of the cell-sap in the cells bordering the air cavities, and water from the neighbouring cells will diffuse into these cells. As this process takes place in all the cells,

there will be a sort of backward suction which may be considered as one of the chief causes for the ascent of water.

The amount of water transpired by the leaf surface of a plant depends upon the structure of the leaf. A leaf having a loose structure possesses a large number of air spaces, and consequently transpiration from such leaves will be very rapid. There are several other factors influencing transpiration. Moisture in the air affects this process. If the air is dry, loss of water will be greater; if saturated with moisture, transpiration will be retarded considerably, if not entirely stopped. If the temperature of the atmosphere is high, transpiration will be rapid and when the temperature is low, the amount of transpiration will be reduced very greatly. Leaves lose more water when there is wind; but on a calm day there will not be much loss.

The stomata play an important part in the regulation of transpiration. The guard cells of the stomata are capable of movement and by this means the opening may be varied. The factors concerned in causing these movements are light, humidity and water content. The mechanism by which the opening is narrowed or widened is very simple. The guard cells are fixed at their ends, but the inner and outer walls are free. As these cells are generally active, especially in the presence of light they draw water from the epidermal cells that are adjoining. The result of this activity of the guard cells is to cause the inner walls to become more and more convex. We know that these cells are firmly joined to each other at the ends, so the increased turgidity forces them apart. If the evaporation tends to increase, or if the water-supply is inadequate, the guard cells lose their turgidity and the inner wall becomes less convex and the strain on the guard cell is removed and consequently the opening is narrowed.

The amount of water transpired by a plant can be determined very easily by weighing the plants growing in pots. Before weighing they should be covered so as to prevent evaporation from the pots.

The amount of water escaping as vapour from the leaves of a plant during the day time is very considerable. A tall well-grown sunflower plant transpires about a litre of water in a day. A large tree such as the Banyan possessing about

200,000 leaves is estimated to give off about 500 litres of water in a day.

FIG. 205. Potometer. (Farmer's.)

In botanical laboratories the loss of water by evaporation from the leaves is usually determined indirectly by the use of a set of apparatus called **potometer**. With the aid of this apparatus it is easy to determine the amount of water which a cut branch takes up within a certain period of time. Since the rate of transpiration from the leaves of a cut branch is about equal to the rate of absorption, the amount of water absorbed may be taken as a measure of the loss of water by transpiration from the leaves. There are several types of potometer, but the one figured here and which was originally devised by Professor Farmer is most convenient to use. This consists of a wide-mouthed bottle fitted with a cork in which are bored three holes, the one intended for the cut branch being a little larger than the other two. The smaller holes

are intended for the insertion of a thistle funnel tube with a stop-cock or a glass rod and for a capillary tube bent at the two ends and provided with a scale. (See fig. 205.) The branch intended for the experiment must be cut under water and the cut end kept under water for some hours or preferably over night. When the branch is required for fitting in the potometer, remove under water carefully with a sharp knife or razor a short piece from the cut end. Submerge under water in a basin or some other vessel the bottle and the cork.

Transfer the cut branch carefully into a tumbler, of course under water, and dip the tumbler with the branch into the water in the basin and then insert the cut end of the branch into the large hole of the cork. Then insert the cork in the mouth of the bottle, press it down well and see that the cut end of the branch is below the level of the water within the bottle. Thrust into one of the small holes the thistle funnel tube or a glass rod, and into the other, one end of the capillary tube, taking care that it is flush with the lower surface of the cork. After lifting the whole apparatus from the water, close the stop-cock and see that the cork is water tight. If necessary wax or plasticine may be used for this purpose. At the free end of the capillary tube a small bubble of air is allowed to get in and then the end is dipped in water. The air-bubble serves as an index to measure the amount of water absorbed. By manipulating the thistle tube or the glass rod the air-bubble may be sent back and several readings may be taken.

Another very convenient form of potometer is the one (see fig. 206) devised by Professor Ganong. It is easy to set up and can be got ready within a very short time. The method of using it may be learnt from the study of the figure. The precautions to be taken as regards the branch are the same as for Farmer's potometer.

The potometer is very useful as it enables us to obtain records very quickly. Further it may be used to obtain results under different conditions, such as still air inside, open air outside, in diffuse light, in sunlight and in situations where there is gentle breeze.

The entrance and evaporation of water from the leaves are only means to an end, and this end is the manufacture of carbohydrates. The primary function of the leaf is undoubtedly photosynthesis. So its structure is such as to facilitate this process in every way. One of the essential conditions for this synthetic work is the access of carbon dioxide. The entrance of this gas into the mesophyll cells is chiefly through the stomatal openings. The epidermis

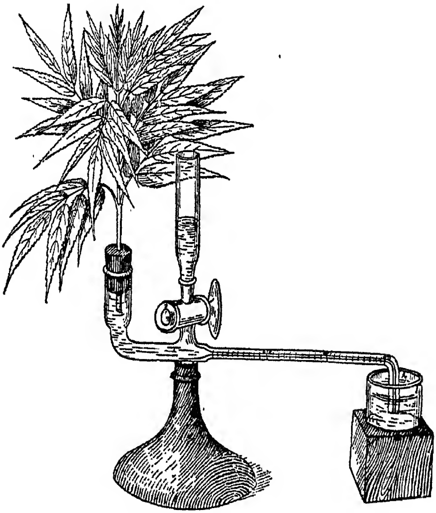


FIG. 206. Potometer of Ganong.

being usually dry and also cuticularised is impervious to this gas. When the stomata are open to facilitate the passage of carbon dioxide into the mesophyll, there is nothing to prevent water from escaping as vapour through the same way. In fact it is impossible to stop this escape of water vapour. So it is clear that transpiration is unavoidable and that it is an accompaniment of photosynthetic work, Transpiration, though an incidental process instead of being

a primary one, is useful as it is an important factor in maintaining the current of water which is necessary to supply water as well as salts to the chlorenchyma. Another advantage of transpiration is the prevention of injury from excessive heat to the plant by lowering the temperature.

Although the unavoidable process of transpiration is necessary, excessive transpiration is a menace to the life of plants. In nature many plants suffer from this and hundreds of them die in consequence. By contrasting the plants of a species growing in places where there is an abundant supply of water with plants of the same kind in dry places one can realise to what an extent excessive transpiration is harmful. On a very hot day we see in cultivated dry fields cholam or other crop plants badly wilting, because the loss of water as vapour from their leaves is more than the absorption of water from the roots. Unless a plant manages to maintain a proper balance between loss and supply of water it cannot thrive. If the soil is well supplied with water then plants do not suffer much. If on the other hand, the soil is dry and water scarce even a small amount of transpiration may prove harmful.

Inasmuch as transpiration cannot be stopped without at the same time interfering with the work of starch formation, plants must be able at least to prevent excessive transpiration. In land plants the epidermis in the leaves are very useful in this connexion. It forms a most efficient water-proof membrane, though thin, in virtue of the fatty character of the cutin in the cuticularised external walls of the epidermal cells. The efficiency of the epidermis can be inferred from the fact that an apple whose epidermis is peeled off loses in three hours twenty times the amount of water that escapes from an intact apple.

Plants growing in very dry regions are in grave danger of losing much water by transpiration and, unless they develope some means to protect themselves against this excessive loss of water, they run the risk of extinction.

By a close examination of plants growing in a dry region, it will be seen that the means adopted by them for protection are most varied. But they are all intended to lead to the same result, the reduction of the transpiring surface.

The epidermis is always ready to check undue evaporation by developing a thick cuticle. There will also be a great reduction in the number of stomata. The palisade parenchyma becomes very much pronounced by becoming vertically elongated and by increase in the number of layers. Outgrowths such as hairs, scales, waxy bloom, etc., are also

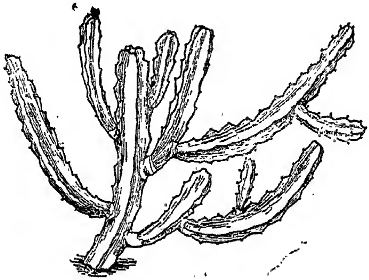


FIG. 207. Boucerosia.

means of protection. In some cases the leaves become reduced, and in others leaves do not at all develop.

Movements of gases and aerating system in plants.—Since the vital process of respiration in plants is dependent upon the supply of oxygen, it is necessary that there must exist in every plant some arrangement to ensure the access of oxygen to all the cells. No doubt oxygen can diffuse from cell to cell, but it can reach only short distances in this manner. By diffusion through cells this gas cannot be expected to reach distant places quickly, and consequently oxygen is not likely to be readily available in sufficient quantity when needed. So the only satisfactory arrangement would be to have spaces in the proximity of cells so that each cell may have at least a part of its surface exposed to air-space. The large number of small and large intercellular air-spaces that we see amongst cells serves this purpose.

While every cell in a plant requires oxygen, cells containing chloroplasts need carbon dioxide in addition to obtain one of the ingredients of the carbohydrate food material which these cells have to manufacture. The primary function of the mesophyll cells of leaves being the work of

carbohydrate synthesis, large quantities of carbon dioxide must be absorbed by these cells. But this gas exists in small quantities only in the atmospheric air, namely three parts in 10,000 parts of air. Therefore, a plant must have in it special facilities for the admission and distribution of carbon dioxide. We find, accordingly, an elaborate ærating system in the higher plants.

The stomata and the lenticels afford passages for the entrance of carbon dioxide and oxygen. The epidermal cells and cork cells do not allow these gases to pass through them, although epidermal cells when not cuticularised may allow these gases to go through them if they are moist. Below every stoma there is a prominent cavity and this is in communication with large air spaces in the spongy parenchyma. Even in the palisade parenchyma there are numerous small intercellular spaces. In fact intercellular spaces are abundant in parenchyma wherever it may be found. So the intercellular spaces in the leaves become continuous with those in the stem. The beginnings of intercellular spaces are seen even in the meristematic tissue at the growing points. These intercellular spaces become larger, irregular and more numerous in older portions.

The aerating system consists of the stomata, lenticels and the most irregular and extensive intercellular spaces found in all the parts of the plant. The aerating system not only attains its maximum development, but it is also very striking in aquatic plants. Large canals or spaces arise in the softer tissues of the stem, in leaf stalks and other parts. Sometimes, especially in the stems, stellate or branched cells with branches in contact only by their tips, leaving large spaces for gases occur. All these air spaces have direct communication with the outside atmospheric air through the stomata only in marsh plants. In submersed aquatic plants no stomata are formed and so the internal atmosphere cannot possibly be directly connected with the outside atmosphere.

The stomata are very minute pores, the area of one pore being when fully open only 0·000092 millimeter on the average. Therefore it is really puzzling how these minute pores could afford sufficient passage for a sufficient quantity of carbon dioxide and oxygen. But we must remember the

fact that air diffuses with very great ease through a membrane drilled with minute holes, especially when these holes are not round but elongated slits. Further, the stomatal passages are not really small for the molecules of oxygen or carbon dioxide. Professor Ganong has pointed out that the capacity of the stomatal openings for gas passage is far in excess of that implied by their areas, and that an ordinary stoma when open, presents to a molecule of carbon dioxide or water an entrance or exit as great, as a passage seven miles wide appears to a man. As already stated the large number of stomata existing within a small area also facilitates the passage. In the Helianthus leaf about 175 in the upper epidermis and 325 in the lower to a square millimeter have been found. A Ficus leaf is said to have none on the upper and 145 on the lower epidermis of the leaf. A leaf of *Zea Mays* is known to have 94 on the upper and 158 on the lower epidermis.

Other factors which influence the inflow or outflow of the gases are diffusibility and solubility of gases in water and their utilization within the plant. The pressure mainly determines the direction of the passage of gases, and in plants there will be always difference between the air inside and outside, inasmuch as the gases oxygen and carbon dioxide are used up and further their solubility and powers of diffusion are not the same. It must be remembered that carbon dioxide is far more soluble in water than oxygen.

The aerating system, no doubt, exists mainly to facilitate the absorption and distribution of carbon dioxide, but at the same time it affords easy passage for the water vapour also.

All plants, like animals, need food for their growth and development; and the substances used by plants, as well as animals, as food, are the organic substances starch, or carbohydrates, proteids and water. Animals obtain these substances from plants or other animals. Except water, the other substances cannot be obtained by plants from the soil. From the materials supplied by water absorbed by the roots and from carbon dioxide, leaves are able to make carbohydrates, and from this substance proteids can readily be prepared.

In a germinating seed the growing embryo gets its food from the cotyledons or the endosperm, where it is stored.

This source of supply lasts only for a short time. As soon as green foliage leaves appear the plant will be able to prepare its food. If it is capable of doing this, we should be able to detect one or other of these stuffs in the leaves. In plants we find starch in all parts. And its presence can be made out by the use of an aqueous solution of iodine. Starch turns blue on coming into contact with iodine, and, therefore, it is easy to demonstrate the presence of starch in leaves by the use of iodine. Obtain some foliage leaves from a plant which has been growing in the light and steep them in hot water for sometime. Next immerse these leaves in alcohol until they become white. Select one or two of the leaves thus bleached and place them in a shallow dish containing iodine solution. After a while they turn blue, or black according to the amount of starch present. If we examine a leaf taken from a plant kept in the dark for sometime for starch, we do not find any. Therefore, we have to infer that starch makes its appearance only when the leaf is exposed to light.

Formation of Starch in leaves.—On exposing a starch-free leaf, detached from a plant kept in darkness for some time, to light by placing the leaf in a vessel containing water, starch will be found in it. From this simple experiment it follows that starch is formed in green leaves. Further, it must be remembered that formation of starch takes place only in parts of leaves actually bathed by the rays of light. Portions of leaves not exposed to light, even though contiguous with the parts exposed to light, are free from starch. These facts can be demonstrated by exposing a leaf for a day, after covering it with a stencilled plate or paper. A leaf thus exposed, when bleached and

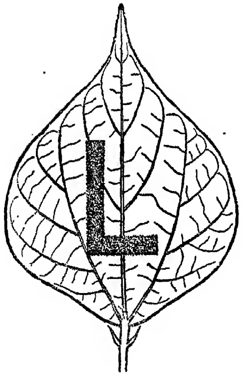


FIG. 208 Stencil-covered leaflet of Dolichos showing starch formation.

immersed in iodine solution turns blue only in places exposed to sunlight, and the portions covered and not exposed remain clear showing the absence of starch. (See fig. 208.)

Starch is an organic compound consisting of the elements carbon, oxygen and hydrogen. We know that there is plenty of water in the foliage leaves, and this is the source for the two elements hydrogen and oxygen. The third element carbon is obtained from the carbon dioxide found in the air and this gas gets into parenchymatous cells of the leaf through the stomata.

From water and the carbonic acid, thus obtained, the leaf constructs starch. For this constructive work, both chlorophyll and light are necessary. This process of constructive work going on in the leaf is called **photosynthesis**, because it is one of combining simple elements into a compound, and this is possible only in the presence of sunlight. The first visible product of photosynthesis is starch, and starch grains are found within the chlorophyll grains. However, in green plants sugar seems to be formed at first and then, it is changed into starch. The cell-sap gets saturated with sugar and this condition will interfere with the work of the protoplasm, if at least a portion of the sugar be not removed or disposed off in some way or other. Further, the activity of the chloroplasts will be very much hampered by this concentration of sugar in the parenchyma of the leaf. Part of this sugar is changed into starch and, as starch is insoluble, there will be no interference with the osmotic activity.

It must not be supposed that the process of photosynthesis is a simple one ; it is a very complicated process and it probably consists of a series of processes. We have already said that oxygen and hydrogen are obtained from water and carbon from the carbon dioxide of the atmosphere. Both water and carbon dioxide are very stable compounds, and as such a great deal of energy is required to split them.

To separate carbon from carbon dioxide the energy required is about the energy expressed by the temperature 1,300 degrees centigrade. Ordinary sunlight is incapable of decomposing carbon dioxide or water, and if so there would be no carbon dioxide or water vapour in the atmosphere.

We know that in a leaf no starch is formed in the absence of light. Of course, starch cannot be expected to be formed in a leaf, if carbon dioxide is withheld. Since light and chloroplasts are essential for the process of photosynthesis we should infer that the chloroplasts are able to obtain energy from the rays of sunlight. Light is absorbed and it is converted into some form of energy, probably electric energy. It is obvious that photosynthesis takes place in the chloroplasts, but we cannot definitely say whether both the protoplasmic stroma and the pigment are concerned, or only one of them in this process. However, it is generally held that the function of the green pigment chlorophyllin is to provide energy for the process.

The foliage leaves are green and so also is the alcoholic extract of chlorophyll. This is because a portion of the white light falling on them is absorbed by them, only a part being reflected or transmitted as green light. With the help of a spectroscope we can determine what portions of the spectrum are absorbed. On interposing between the light and the spectroscope a solution of chlorophyll, we find that a part of the red and orange and a good portion of the blue and violet, disappear completely from the spectrum, while the green is unaffected. From this we have to infer that the rays of light absorbed by chlorophyll are concerned in photosynthesis. That it is so can be demonstrated easily. Plants, from whose leaves starch has been depleted by keeping them for some time in darkness, when exposed to green light show no starch in their leaves, while it is abundant in the leaves if exposed to red and white light. Under blue light a certain amount of starch is formed. Thus it is clear that light absorbed by chlorophyll, especially the red rays, is very effective in food-formation.

We know that in a leaf no starch is formed in the absence of light. Of course starch cannot be expected to be formed in a leaf, if carbon dioxide is withheld. Since light and green colour are essential for this process we should infer that the green chloroplasts are able to obtain energy from rays of light. Light absorbed and converted into electric energy is used for the separation of carbon from the carbon dioxide.

In the leaf carbon dioxide and water are in some way broken up and their elements are re-arranged so as to form carbohydrates, oxygen being given off. The evolution of oxygen takes place only when the plant is exposed to sunlight. That oxygen is given off, when photosynthesis is going on, can very easily be demonstrated. Place in a glass vessel, which is filled with water a few leaves of any aquatic plant, such as Ottelia, Hydrilla, Vallisneria, etc. Invert over the submerged leaves a glass funnel, and then invert over the funnel tube a test tube filled with water. On exposing the whole of the apparatus to sunlight for sometime, bubbles of gas will begin to rise from the cut ends of petioles or branches. After an hour or two a considerable amount of gas will be accumulated in the upper part of the test tube. This gas will make a red-hot splinter burst into flame, and this is the regular test for oxygen. The evolution of oxygen from green plants goes on as long as there is sunlight and carbon dioxide.

The special feature of leaves is to make carbohydrate food-material, and there the spongy and palisade parenchyma are directly concerned in this work. From the very simple substances water and carbon dioxide the chloroplasts manufacture sugar with the assistance of the energy derived from sunlight. The exact details of the process are not certainly known. The hypothesis advanced by Von Baeyar is accepted by physiologists. According to this hypothesis carbonic acid is at first reduced by some means or other to formic acid and this later into formaldehyde. From formaldehyde sugar is formed. All these details may be represented by the following chemicals equations :—

$$\underset{\text{Carbonic acid}}{\underset{\text{or OH. COOH}}{CO_2 + H_2O}} = \underset{\text{Formic acid}}{H.\ COOH} + O$$

$$\underset{\text{Formic acid}}{H.\ COOH} = \underset{\text{Formaldehyde.}}{H.\ COH} + O$$

$$\underset{\text{Formaldehyde}}{6\ (H.\ COH)} = C_6H_{12}O_6.\ \text{(grape sugar)}$$

The first product of photosynthesis is sugar and, in most cases, glucose although cane sugar makes its appearance in a few plants.

The amount of sugar resulting from photosynthesis depends upon the supply of carbon-dioxide and the intensity of light. Up to a certain limit the more the carbon-dioxide the more is the sugar formed. But too strong a light retards the formation of sugar. There is a minimum and maximum intensity of light for this. Of course the limits vary with the kind of the plant. To have a general idea of the amount of sugar formed, we may take as a conventional average figure, one gramme as the quantity made by one square meter of leaf space, in one hour in diffused light.

In leaves starch is found in abundance within the chloroplasts, and so this is to be considered as the first visible product of photosynthesis, though not the first product. The formation of starch, it must be remembered, is not dependent upon light. In stems, tubers and other parts of plants to which light cannot have access starch is found. As a matter of fact starch is formed from sugar. The starch grains found in chloroplasts are very minute, whereas storage or reserve starch grains are large.

Sunlight being the source of energy for photosynthetic work, it is obvious that in its absence no sugar can be formed. Further, the formation of chlorophyll also is dependent upon light. Seedlings grown in darkness are devoid of green colour and become tall.

The chloroplasts need only a light of a certain intensity and if the light is of greater intensity than that, chloroplasts are injured. But when light becomes intense, the injury is avoided either by the movement of the leaves as a whole so as to change the incidence of the light rays, or the chloroplasts move away towards the sides of cells. Out of the light falling on the leaves only about 40 to 70 per cent is absorbed by the leaves, and only 10 to 20 per cent actually enters the chloroplasts, and the amount actually utilised in photosynthesis is still less, being only 0·5 to 3 per cent.

The process of food making is not completed with the formation of sugar. Besides sugar nitrogenous material is

also needed in the nutrition of plants, because protoplasm consists mostly of proteids. Therefore proteids also must be manufactured by the plants. The process of proteid synthesis does not seem to be restricted to any particular organ like photosynthesis. The presence of chloroplasts is not a necessary condition, because plants without chloroplasts, such as fungi are able to manufacture proteids. It can take place in light as well as in darkness and possibly in any living cell. In spite of the fact that in any living cell this process can go on, there is every reason to think that most of this work is carried on in the leaves. Large quantities of the nitrogenous substance in the form of amides are found in mature leaves, especially when their activity is at its height, and this cannot be accounted for except by thinking that it is made in the leaves.

For the elaboration of proteids, substances containing the elements carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus are needed. Inasmuch as the sugar contains

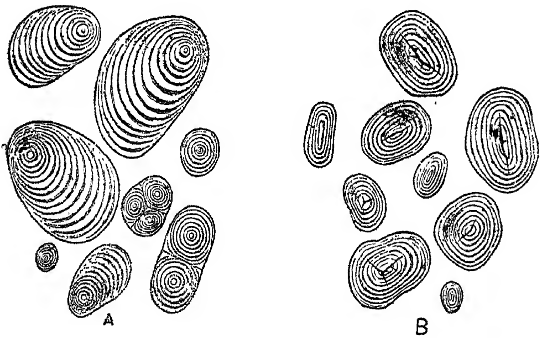


FIG. 209. Starch grains. A, Starch grains of Potato. B, Starch grains of *Dolichos Lablab*. × 500.

carbon, hydrogen and oxygen, it is evident that this substance can be utilized as a foundation material in the process of proteid synthesis. The water which is absorbed by the roots and which reaches the mesophyll of the leaves contains salts such as nitrates, sulphates and phosphates. Since amides make their appearance in leaves we have to suppose that

carbohydrates are converted into amides. Later on amides become modified into several kinds of proteids by the incorporation of the elements sulphur and phosphorus contained in the sulphates and the phosphates. The energy needed for the dissociation and combination of this proteid synthesis comes from chemical actions connected with respiration.

In this world the only place where organic matter is formed from simple inorganic substances is the green leaf. All organic matter existing in this world, however different they may be, wherever they may be found must have been derived or formed from substances manufactured by the leaf. So nature's laboratory for the formation of organic matter is the chloroplast found in green plants. The life of the whole of the organic world is dependent on the process of photosynthesis. If there is no photosynthesis no animal can live. All the stored-up energy of this world is traceable directly or indirectly to this process.

CHAPTER X

FOOD OF PLANTS

Nature of plant food and its utilization.—We know that plants manufacture large quantities of organic substances, and obviously these are intented for their use as food. What constitutes the food of plants may easily be inferred from a consideration of the reserve food stored in seeds. The food required for the growth of a seedling as well as for the growth of an adult plant must be the same. From a study of the structure of the seeds and their germination we know that the reserve stuff consists of starch, sugar, fat or oil and proteids, and that these substances are used up during germination and growth of the seedling. Both plants and animals use the same kind of material as food, but plants differ from animals in being able to make these substances from simple mineral substances. The food material is used by the plant for two purposes. Plants grow and, therefore, they need material from which to build up their tissues. They are able to assimilate the food material into their own living substance. The nutritive material, it must be remembered, is useful to the plant only after it has undergone various chemical changes. All the chemical changes occurring in plants constitute **metabolism.** Those processes which result in the formation of more complex substances and lead to the increase of material constitute **constructive metabolism** or **anabolism.** One use of food is thus to serve as material from which to build up the various parts of the plant body, and the other use is to supply energy which must necessarily be expended in all kinds of work the plant has to do. When protoplasm or other material is made use of for releasing energy it diminishes in quantity instead of increasing. In fact, the supply of energy is due to the breaking down of complex substances built by the activity of protoplasts. These chemical changes resulting in the loss of material are included under the name **destructive metabolism** or **katabolism.**

Storage of food.—Plants, in virtue of the possession of chloroplasts, are in a position to make large quantities of food material. Inasmuch as only a portion of this can be utilized in the formation of new tissues and in the repair of protoplasm, accumulation of food is inevitable. The surplus food is stored in various parts of the plant. This storage of food material is undoubtedly of great advantage to plants, because the demand for food is not the same at all times. Sometimes the photosynthetic activity may be at a standstill, and yet the need for food may be great. During the time in which the plant is vigorously growing more food may be needed. On all these occasions the stored food may be utilized.

The most convenient places for storage are the seeds, stems and roots. The leaves of a plant are highly specialized organs intended to perform the definite work of making food, and, as such, they are unsuited to serve as storage organs, although the photosynthetic sugar may be temporarily stored as starch in chloroplasts. If the mesophyll cells of leaves become permanent storage places for reserve food, the main function of food-making would be interfered with very much. Stems and roots, on the other hand, in virtue of the possession of parenchyma in abundance, are particularly well adapted for storage. If sections of stems and roots are examined, starch grains will be found in most of the parenchymatous cells containing protoplasm. The modified stems, rhizomes, tubers, corms, etc., contain large quantities of reserve food. In fact the modification in these cases is the result of the excessive storage of food material. As the reserve food is in close proximity to the growing points in these parts of plants they are capable of quick and vigorous development.

Storage forms of food.—The reserve food, wherever it is stored, consists of carbohydrates and nitrogenous substances. The most common forms of carbohydrates occurring as reserve stuff are starches, sugars and fats or oils. Different kinds of proteids and amides are the chief representatives of the nitrogenous kind.

Starch.—This is undoubtedly the most common reserve stuff and it is also one of the most stable and permanent

forms in which the food is stored. Starch occurs as grains in all parts of the plant, and these grains are especially abundant in seeds, rhizomes, etc., and this is the reason why man uses them for food. The food value of tubers, rhizomes and corms mainly depends upon the amount of starch contained in them.

There is a considerable amount of variation in the shape, size, and lamination of these grains according to the kind of plants. Generally starch grains in seeds, tubers and rhizomes are much larger than in the ordinary roots and stems. The characteristic striations of starch grains are either concentric as in *Dolichos Lablab* seeds or eccentric as in potato. Some times irregular cracks also occur. (See fig. 209.) The formula for starch is $n\ (C_6H_{10}O_5)$. Just as starch grains found in chloroplasts are formed from sugar, so even reserve starch grains are formed from sugar, and leucoplasts are concerned in this transformation.

Sugar.—Although glucose and fructose are almost always found associated with active living cells, they do not occur in large quantities. The only sugar which accumulates in any quantity to form a storage product is **cane sugar** or **saccharose.** As examples we may mention sugarcane, the beetroot and some of the palms.

Cellulose and Inulin.—In some seeds, such as those of date and coffee, the reserve carbohydrate is in the form of cellulose, or strictly speaking, **hemicellulose.** The cell walls of the endosperm in these seeds become excessively thickened, and the thickening is due to the deposition of hemicellulose. In some plants belonging to the family Compositæ the carbohydrate occurs as **inulin.** The bulbs of Jerusalem artichoke is a good example for this.

Fat or oil.—In many seeds the reserve stuff takes the form of fat or oil and these seeds are of very great economic importance. Oil usually exists as very fine drops, diffused in the protoplasm of the cells of the endosperm or cotyledons.

Proteids.—All seeds contain proteids, but in some in small quantities and in others in large quantities. If they are in the form of minute amorphous particles or in the form of a net-work, they cannot be made out. Sometimes they

assume regular shapes as in castor and gingelly seeds and then they are called "**aleurone grains.**" In the cereals the proteid accumulates in a layer of cells just outside the endosperm and this layer is therefore called "**aleurone layer.**" In many leguminous seeds proteid is present as minute particles side by side with starch in the cells of the cotyledons.

It must not be supposed that these various kinds of reserve food occur independently. They always occur associated together although one form may predominate.

Digestion.—In all higher plants plant food is formed in one place and it is stored in a different place which is usually somewhat far removed from it. So food has to be translocated from the place of production to the place of storage, and it has also to move from there to places where it is to be used. Generally the reserve food is incapable of diffusing through cells in the form in which it is stored. Therefore, it has to be transformed into a soluble and diffusible substance, if it is to migrate into other parts of the plant. This transformation of an insoluble substance into a soluble one and of an indiffusible one into a diffusible one is called digestion. The changes characteristic of digestion result in the breaking of compounds into simpler substances. The agents concerned in this process are enzymes, of which there are many in plants.

Of the enzymes acting on carbohydrates the one affecting the starch, called **diastase**, is found widely distributed in plants in the leaves, in germinating seeds and in other places where starch is stored. Diastase converts starch into malt sugar.

$$\underset{\text{Starch}}{n\,(C_6H_{10}O_5)} + \underset{\text{Water}}{6\,H_2O} = \underset{\text{Maltose}}{C_{12}H_{22}O_{11}}$$

There seem to be two distinct kinds of diastase, one corroding the grains in an irregular manner from outside, so that the grain loses its usual shape, and the other dissolving the grain evenly and uniformly, so that the shape is not affected though there may be a decrease in size. **Invertase** is the enzyme which changes the cane sugar into glucose and fructose.

$$\underset{\text{Saccharose}}{C_{12}H_{22}O_{11}} + \underset{\text{Water}}{H_2O} = \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

Maltose is changed into glucose by **maltase** and the sugar inulin is converted into fructose by **inulase.** Another enzyme which turns hemicellulose into sugar is termed **cytase.**

Fats and oils get split into fatty acids and glycerine by **lipase.** Proteids are transformed into soluble proteids by what are called **tryptic** enzymes.

Conducting tissues.—The food materials formed in the mesophyll tissue of the leaves must sooner or later migrate to storage places, or to those parts of plants where growth is actively taking place. That there is a translocation of carbohydrate from the leaves is easy to demonstrate. If a leaf, detached from a plant just at sundown, is bleached in the usual way and then tested for starch, there would be an abundance of starch. On the other hand, a leaf detached from the plant at sunrise and similarly tested for starch would show only a small quantity of starch.

The carbohydrates and nitrogenous substances formed in the cells of leaves diffuse into the parenchymatous cells surrounding the veinlets. And from there they pass on to the veins through the veinlets.

Since the veins join the midrib of the leaf food material will pass through the midrib into the petiole and thence into the stem. The fact that food materials actually pass through the veins is easy to prove. If in a leaf which is lobed we cut one of the main veins in the evening and detach the leaf in the morning and subject it to a test for detection of starch, we would find plenty of starch in the lobe into which the severed vein runs and in the other lobes the amount of starch would be very much less or there may be none.

As soon as the food reaches the stem it may pass up, or down, or in both the directions. Since the food material travels through the veins of the leaves and then through the vascular bundles of the petiole and stem, it is obvious that it must travel through the xylem or through the phloëm. We have evidence that the tracheal tissues of the xylem and the sieve tubes of the phloëm carry the food. The xylem vessels are particularly well adapted for a rapid movement of water and so sugar, amides and proteids which are soluble in water can easily be transported through the xylem vessels. But

the great portion of the food material passes through the phloëm, and in fact it is the highway for the vertical passage of food through the stem. The sieve tubes contain plenty of carbohydrates, proteids and amides. If the continuity of the phloëm is wholly interrupted by girdling a stem all round, down to the wood, it will be seen that growth is slow or absent below the girdle. A cutting with its bark completely girdled at the lower end placed in the soil or water produces adventitious roots in abundance above the decorticated portion and, in the part below, few or none appear. In the case of plants having bicollateral vascular bundles, removal of the bark would interrupt only the external phloëm, and the inner strands of phloëm would be intact and food would pass all right.

Besides the vertical transmission of food through the vascular bundles, there may also be translocation in the direction especially through the medullary rays. In this case the passage may be for storage or for the removal of stored food stuff. The intimate connexion of the medullary rays with the cells of the xylem on one side and with those of the phloëm on the other, and their large number make them efficient organs, not only for storage but also for radial translocation.

CHAPTER XI

NUTRIENT SALTS AND WATER-CULTURE

THE water absorbed by the root hairs from the soil is not pure water. It usually contains all the soluble salts present in the soil. Water is of fundamental importance to the life of the plant, and the mineral salts also are necessary for the growth of plants. If we try to grow plants by supplying them with pure water only they do not thrive, whereas they grow well in river water, and still better is the growth of the plants, when a watery extract of soil is given.

The water in the soil contains a number of mineral salts of which many are useful for plants, and the salts at the disposal of plants on the surface of the earth are really unlimited. Water also is generally available over a large part of the surface of the earth. This accounts for the existence of green vegetation everywhere in this world.

A knowledge of the chemical composition of plants will enable us to know what elements plants need for their growth. In a living plant the most abundant ingredient is water, and in some cases, especially in fleshy plants, it may be as high as ninety per cent of the total weight of the plant. In the case of woody plants it may be as much as fifty per cent. So the solid substances in a plant may vary from ten to fifty per cent.

When plants are burnt in a fire at first they get charred and in the end the whole of the lot is burnt away and there is left only some fine white ash. The conversion of the parts of plants into charcoal, while combustion is proceeding, is a sufficient proof that there is carbon in the body of a plant. Very nearly half the dry weight of a plant consists of carbon. This element forms not only a predominant one but also the most important element in all the compounds which build up the living organism, because the molecular combi-

nations which carbon is capable of forming is most varied. Since during the process of combustion of a plant water vapour, carbon dioxide, ammonia and a gas containing sulphur are given off, it is evident that water, carbon, nitrogen and sulphur besides the ash must form the constituents of the plant body.

The percentage composition of plants gives an indication that carbon and its compounds or organic substances are of great importance to plants. But, so far as the ash constituents are concerned, it gives no clue as to which constituents are essential and which not. Further, these constituents do not exist in the plant in the same combination as in the ash, for ash is the result of combustion.

If we compare the results of the analysis of a number of different kinds of plants, we find that the number of inorganic substances present in plants is very considerable and that whilst certain elements are present in all plants others occur only in certain plants. For example, plants growing in some soils contain in their ash traces of zinc, copper, cobalt and other rarer elements. The same species of plants growing in other soils do not show even a trace of such elements. Therefore we may regard these as being not essential for the plants. The elements potassium, calcium, magnesium, phosphorus, sulphur, iron, silicon, chlorine and sodium are universally present in plants, and, therefore, they are of general occurrence. At the same time, we must bear in mind, that because a substance is invariably present in a plant it does not necessarily follow that it is essential. What elements are essential and what are not can be determined only by experiment.

Taking advantage of the fact that plants take in everything they need only through the medium of water, Sachs and Knop during the middle of the last century reared plants by the method of water-culture and demonstrated that certain elements are essential, while others are not. In water-culture, plants are made to grow in glass jars containing distilled water to which certain known salts are added, in some definite proportions. They may be grown in pure sand also by watering the sand with the prepared solution (sand-culture).

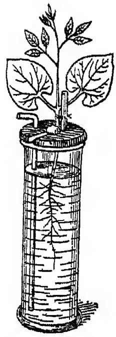


FIG. 210.
Water-culture.

For water-culture experiments seeds whose seedlings are capable of rapid growth, such as those of beans and maize, are germinated in clean moist sawdust or sand ; and when the radicle is well developed the seedling is fixed in the lid of the jar (see fig. 210). For success in water-culture experiments the jars should be very clean. So they must be thoroughly rinsed with dilute nitric acid first, and then with an aqueous solution of corrosive sublimate. By repeated washings with boiled distilled water all traces of corrosive sublimate should be removed, as this substance is a deadly poison.

The culture solutions generally used in the water-culture experiments are numerous and some of the important ones are these :—

1. Knop's solution :—

Calcium nitrate	2 grammes
Potassium nitrate	0·5 gramme.
Magnesium sulphate	0·5 „
Potassium phosphate	0·25 „
Iron salts	a trace.
Water	1 to 2 or 3 litres.

2. Sachs' solution :—

Potassium nitrate	2 grammes.
Sodium chloride	1 gramme.
Calcium sulphate	1 „
Magnesium sulphate	1 „
Calcium phosphate	1 „
Water	2 or $2\frac{1}{2}$ litres.
Iron salts	a trace.

3. Von Crone's solution :—

Potassium nitrate	1 gramme.
Calcium sulphate	0·25 gramme.
Magnesium sulphate	0·25 „
Ferrous phosphate	0·5 „
Water	1 or 2 litres.

Of these three Von Crone's solution is the best and it gives very good results.

For fixing the seedling in the lid of the jar antiseptic cotton or asbestos, rendered antiseptic by burning it in the flame of a spirit or gas burner, should be used, and care should be taken that the roots only are in water and the hypocotyl is well above the level of the solution. As the amount of oxygen that the culture solution is able to retain dissolved in it is very small in quantity, it is necessary to force air into the solution, at least once a day, for fifteen minutes in the form of small bubbles so as not to cause any damage to the roots. A very simple and convenient method of forcing air into the culture solution is shown in fig. 211.

The salts used in culture solutions consist of the elements **nitrogen, sulphur, phosphorus, potassium, magnesium, calcium** and **iron.** All these seven elements and the three elements **hydrogen, oxygen** and **carbon** are absolutely necessary for the growth of plants. So these ten elements must be considered as the **essential elements** for the growth

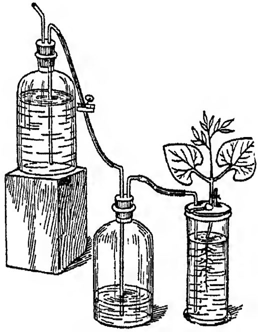


Fig. 211. Apparatus for aerating water-culture jars.

of plants. If the culture solution is wanting in any one of these elements, plants do not grow well. For instance, if in the culture solution ferrous phosphate is omitted and calcium or potassium phosphate is added instead, the element iron will not be available. A plant grown in the solution lacking in iron would have pale yellow leaves instead of green leaves. The results of the growth of plants in defective solutions may be inferred from the fig. 212.

From culture experiments we learn that plants can grow to maturity, flower and set good seed, only if they are supplied with salts composed of the seven essential elements mentioned above. The amount of salts needed is indeed very small. Further, the essential elements must always be presented in the form of appropriate chemical combinations, because the nutritive value depends upon this. For example all substances containing nitrogen are not suitable. Most plants obtain this element from nitrates and some from compounds of ammonia.

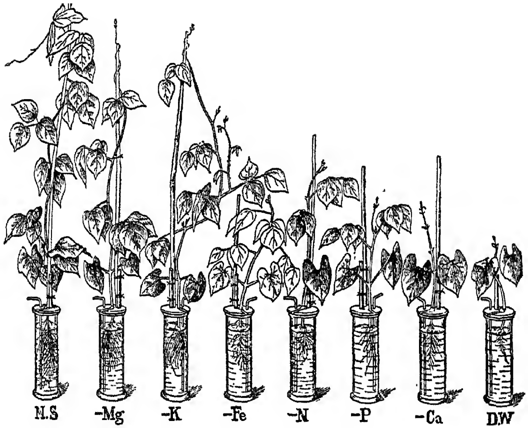


FIG. 212. Plants grown by the method of water-culture in different solutions.

For the full development of the plant it is necessary that only a certain minimum amount of each essential element must be supplied, although the plant may assimilate much more than the minimum amount when the supply is abundant. At any rate the quantity must not exceed the optimum limit.

In the case of some plants the presence of a non-essential element may be a distinct advantage to the plants. For example, the presence of silicon in the epidermal cells of certain plants may protect them from the depredations of insects, and thus save them from extinction.

Those elements which we consider essential enter into the composition of the protoplast. We know that the elements found in protoplasm are C, H, O, N, S, and P. In young organs, especially in meristem tissues large amounts of potassium and magnesium are found. Iron seems to be necessary for the formation of chloroplasts. Calcium, though not present in protoplasm, occurs in certain layers of the cell-walls. It seems to be useful in connexion with metabolism. By combining with oxalic acid and forming calcium oxalate, it prevents the injurious effects of the oxalic acid and it is also said that in some way it is useful in connexion with the transport of plastic carbohydrates. Salts, both organic and inorganic, are also useful in the maintenance of turgidity.

The profusion of vegetation is due to the fact that green plants utilize only such of the substances as are very widely distributed on the surface of the earth. The ordinary salts found in the soil contain the essential elements. At the same time plants do not use all the elements, though widely distributed and abundant. For example, the element sodium has a world-wide distribution and yet it is not an essential element. Sometimes plants accumulate in them large quantities of certain elements, even though such elements may be present, in such small quantities, that their presence could not be detected even by chemical tests. Sea weeds contain large quantities of iodine, although it is difficult to demonstrate its presence in sea-water.

CHAPTER XII

RESPIRATION OF PLANTS

THE processes concerned in the nutrition of plants and the work of individual organs of a plant have been dealt with in the previous chapter. We have now to turn our attention to the process of respiration of plants, although it has already been referred to in another chapter. This process is a very important one and it is not easy to grasp, at the first presentation, all the facts connected with it. We should also try to learn the part plants play in the economy of nature.

All living beings are continuously at work, so long as they are alive. And the performance of vital functions and the maintenance of life are dependent on the continuous supply of oxygen. Should the supply of oxygen be cut off, all the activities in an organism will be brought to a standstill and, unless this gas is supplied within a reasonable time, the plant or animal will lose its vitality.

It is a well-known physical law that work, whatever its form and wherever done, involves an expenditure of energy. An engine at work is consuming energy supplied to it by the coal or fuel. When the coal or fuel burns, heat is generated and heat is one form of energy. A plant also is as truly a machine as a steam engine, so long as it is alive. Therefore, the work of a plant also implies a supply of energy. Whence does a plant get energy for doing its work ?

It is a matter of common observation that an animal doing work breathes and that breathing increases, when the work becomes harder. Further in the tissues in which growth or other work is going on rapidly there is an increase in the products of respiration. So, we have to conclude that the power of doing work is connected with breathing in some way. Breathing, or respiration, as it is called, consists in taking in oxygen and giving out carbon dioxide and water. Some experiments have already been described by which we learn that plants also respire. A plant, from the moment it begins its life until its death, continues to respire incessantly.

When respiration ceases the plant also dies. This intimate relation existing between respiration and the vital functions of the plant gives us a clue to the source of energy which plants need for their work. During respiration considerable quantities of carbon dioxide are given off by the plant, and it is obvious that the carbon contained in this carbon dioxide should have come from inside the plant. This being so, respiration must lead to loss of weight. Further, this loss has to be made good, if starvation is to be prevented. We know that sugar is formed in plants in the leaves and this is the basic substance utilized for all other organic substances. Therefore, this sugar is the source of the respiratory carbon.

All green plants are able to prepare carbohydrates in large quantities, and for the preparation of these substances energy is obtained from sun's rays. The presence of food, or its mere accumulation in a plant body can no more be expected to supply energy than the mere heaping of coals in a steam engine. To set the engine in motion the coal should be ignited. That is to say, the energy lying locked up in coal for untold ages as latent energy has to be released by combustion. Similarly, a plant can make use of the energy contained in the food-stuff only when it is let loose from the food material. The objects of combustion in an engine and respiration in plants are one and the same. In the engine during combustion heat is generated and it acts on the boiler, piston, etc. Respiration also is believed to be oxidation, only it is less violent than that going on in an engine. Further, it is controlled by protoplasm.

Even in respiration a certain amount of heat is produced, as in the combustion of coal in an engine. But, it is conducted away as soon as it is produced, because a plant possesses a large extent of surface relatively to its mass. Further, the oxidation taking place in a plant is very much less violent. However, in parts of plants where growth is actively going on, there will be a distinct rise in temperature, if care is taken to prevent rapid conduction. The flowers of several Aroideæ sometimes show a rise of several degrees above the temperature of air. Although in the steam engine it is the heat that is used up, in a plant heat is only incidental,

and it is not used by the plant for its work. It is not possible to make out the form of the energy that is used by the plant for its work. We know nothing about the full structural details of the protoplasmic machinery in the cell. The respiratory process, if we take into consideration only the end products, may be expressed as a chemical equation thus :—

$$C_6H_{12}O_6 + 6\ O_2 = 6\ CO_2 + 6\ H_2O.$$

The process of respiration should not be considered to be a mere exchange of the gases oxygen and carbon dioxide, although oxygen is consumed and carbon dioxide is released during this process. The essential feature of respiration is the decomposition of protoplasm or some of the proteins forming its constituents by the action of enzymes. Some physiologists consider respiration to be a process of oxidation of food substances stored in the cells, the protoplasm playing little or no part beyond initiating the process. According to this view food substances are decomposed either by the protoplasm or the enzymes, without their being assimilated into the living substance. Active respiration is always accompanied by the disappearance of accumulated carbohydrates and, therefore, it is believed that these are directly decomposed.

There are other physiologists who hold respiration to be a process of decomposition of the protoplasm or its protein constituents by enzymes or other means. A supply of oxygen is undoubtedly essential for the process, but it does not combine directly with carbon compounds. Its chief use is said to be to combine with and remove substances formed by the breaking down of protoplasm or proteins, so as to prevent their accumulation. The presence of these secondary products may seriously interfere with the process of respiration. So their removal is necessary to facilitate the continuance of the process until its completion. The carbohydrates are used up in the repair of proteins.

Even if the process of respiration is oxidation, it is undoubtedly very different from ordinary combustion. The oxidation connected with respiration is initiated and kept going by the protoplasm directly or by enzymes. The only

point of resemblance between combustion and respiration is the result.

In this universe no energy can be created anew or completely destroyed, but it may change its form. So the energy locked up in the food of plants must have been stored by expenditure of energy. Whence did this energy come? The carbon dioxide in the air is split inside the cell of a leaf within the chlorophyll grain into carbon and oxygen by the energy supplied by sunlight. The oxygen escapes and the carbon combines with the elements of water and forms a sugar. This is really transformation of the energy of light which is kinetic, into latent energy in sugar. The energy locked up in compounds is latent in the form of unsatisfied chemical affinity, and when these are subjected to the chemical processes constituting respiration, then kinetic energy is again given out and this is used by the plant.

Thus we see that the energy stored in the food material as latent energy is let loose, by the process of respiration, as kinetic energy for the use of the plant. An eminent vegetable physiologist describes the food materials of a plant as a kind of storage battery charged by the sun and discharged by respiration.

Both plants and animals respire, and so we should expect the carbon dioxide to accumulate in the atmosphere. If this influx of carbon dioxide is not checked, it is obvious that the surface of our planet will soon cease to have living organisms. But in nature, in spite of the universal katabolism going on in the form of respiration, the atmosphere never becomes foul. This forces us to the conclusion that there must be some other process going on in nature which prevents the accumulation of carbon dioxide in the atmosphere. Plants having chloroplasts take up all the carbon dioxide, and evolve oxygen, as long as there is sunlight. The air rendered foul by the breathing of plants and animals is thus made pure by green plants.

The process of photosynthesis carried on by green plants is to a certain extent antagonistic to the process of respiration. The former process takes place only during the daytime and in green parts of plants, whereas the latter goes on always, both day and night and in protoplasm, and does not depend

upon the green colour. Respiration leads to loss of weight, but photosynthesis brings about an increase in weight; energy is released by the former and it is stored in latent form by the latter. Though the process of photosynthesis takes place only during the daytime, it is at least twenty times more active than the respiratory process.

The part played by the green plants is of the utmost importance in the economy of nature. The main work of a chlorophyll bearing plant is the continual transformation of the energy of sunlight into latent chemical energy. The chloroplastid is an apparatus imbedded in protoplasm for catching the sun's rays. In fact the plant is a machine whose work is to store up large quantities of latent energy, by the absorption of sunlight. Thus we see that the source of energy is the sun. As already pointed out the formation of starch from simple inorganic substances is the only way by which organic matter is formed upon our planet. "Nature does not possess any other laboratory for the formation of organic matter except the leaf, or more strictly, the chloroplast." The energy thus stored up is released by the process of respiration.

CHAPTER XIII

SPECIAL MODES OF NUTRITION

A GREAT majority of flowering plants are able to manufacture, during their lifetime, complex organic substances out of water, some salts and gases obtained from the soil and the atmosphere. All such plants are normal land plants and all the processes taking place in them and subserving nutrition are also to be considered as normal. But amongst flowering plants there are a few that show a departure from the normal modes of nutrition in certain respects. For example, plants like Viscum, Loranthus, Striga, and Santalum, instead of growing in the soil, attach themselves either to the branches or roots of other plants. And yet all these plants carry on the function of photosynthesis as well, as those plants that grow rooted to the soil. But for water and salts they are dependent on other plants, as they cannot get them from the soil. On account of this partial dependence such plants as these are called **semiparasites**. Because of the change in their habit, semiparasites have their roots modified, so as to suit the altered

FIG. 213. Viscum on a branch of *Pongamia glabra*. 1 and 2 are Viscum plants.

conditions. These modified roots, or **haustoria** are specially adapted to obtain water from the wood of their host plants.

The Viscums and the Loranthuses found growing on the branches of trees, such as the Margosa, the Mango, the Tamarind and Pongamia are typical semi-parasites. There is nothing in the stems and leaves to suggest their parasitic life, but the roots plainly indicate this tendency. Further, the modifications in the root are of such a nature as to enable to penetrate the bark and become intimately connected with the inner woody tissue of the host plant. Without this intimate connexion, these plants cannot absorb water and it would be impossible to secure fixation to the branch of the host plant.

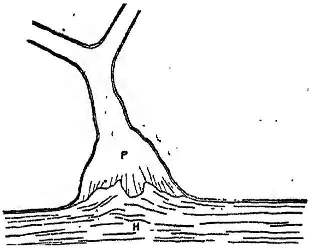


FIG. 214. A section through a haustorium of Viscum showing the fusion of xylem between the host and the parasite. P, parasite Viscum; H, host plant Pongamia.

Viscums usually attach themselves to their host plants in only one place. On the other hand species of Loranthus secure attachment to a number of places by producing numerous haustoria, and, therefore, these are more destructive to their host plants than Viscums. All the species of the family Loranthaceæ are semi-parasites and they invariably grow on the branches of the shoot-systems of trees. (See fig. 83 for a Loranthus parasitic on a branch of *Albizzia amara.*)

We have next to consider flowering parasites growing on the roots of the host plants. One of the most common and widely spread plant of this kind is *Striga lutea.* It flourishes in fields, fallow or cultivated, and it grows from the roots of grasses, cereal plants or weeds. This Striga attaches itself to the root of the host in only one place, but Santalum, Ximenia, other species of Striga and Cansjera produce a number of haustoria and secure attachment in many places on the root-system of the host plant.

The semi-parasites so far mentioned have abandoned the usual mode of life of a green flowering plant, only in the manner of obtaining water and salts. So the advance in the direction of parasitism is not very great. Some species of Striga, however, show a little more advance in this direction. For instance, *Striga orobanchoides*, which is usually found parasitic on Lepidagathis, Opuntia or Euphorbia is dark purple in colour and there is not much of green colour in it. Besides this, the leaves are reduced and scale-like. (See fig. 82.) So this plant cannot be expected to manufacture carbohydrates and, therefore, it must obtain them from the host plant. Other striking examples of flowering parasites that are devoid of chlorophyll and are parasitic on the roots or stems of plants are the Orobanches, Cuscutas and Cassytha. Amongst the Orobanches, *O. cernua*, which is so destructive to the tobacco crop is widely distributed and well known. The tangled masses of yellow or greenish yellow threads found on trees such as Eugenia, Acacia and Buchanania are all of the species. *Cassytha filiformis*. *Cuscuta chinensis* generally attacks herbs such as *Ipomœa biloba*, *Launæa pinnatifida*, etc. The threads twine round the stems and cling on to the support by means of numerous haustoria produced

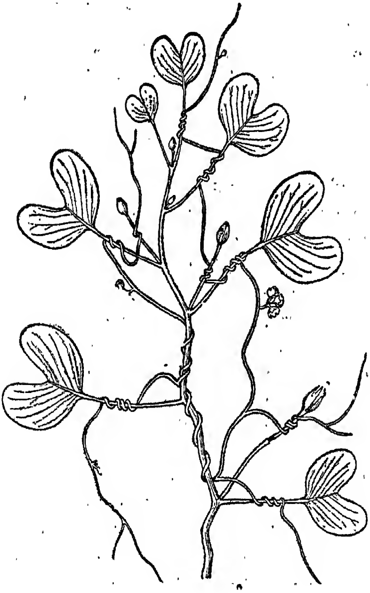


FIG. 215. Cuscuta parasitic on *Ipomœa biloba*.

at short distances. Obviously these cannot do the work of photosynthesis.

In all flowering parasites that do not produce the chlorophyll, the vegetative part of the plant should be expected to be very much reduced. The most conspicuous part of the plant body in all these plants is the infloresence. The wonderful root parasite Rafflesia, already mentioned in a previous chapter, is nothing but a huge flower measuring about a yard across.

On account of their parasitic habits, these plants are at a great disadvantage in the matter of dispersion of seeds and the securing of proper places for germination, compared with the ordinary land plants. In spite of this, we find all these parasites flourishing well all over the country. Very often these become serious pests; for instance, in many a place the plant *Striga lutea* grows so luxuriantly, as to be the despair of a farmer. We meet with trees full of Viscum or Loranthus all over the country. Therefore, we have to conclude that these plants have some special features to enable the seeds to find suitable places for their germination. All parasites should be able to find out their appropriate hosts, when they are young. Unless the seeds are close to their host plants, the seedlings run the risk of not finding their hosts. This risk is minimised in all parasites by their ability to produce seeds in large numbers. For example, a single Striga plant produces a mass of fine seeds numbering over sixty thousand. Even in Viscum and Loranthus seed production is fairly extensive, though not so profuse as in Striga or Orobanche. But the fruits are sticky and edible. So birds peck these fruits and as the seeds stick on to their beaks they get rid of them, by transferring them to the twigs or branches of trees. This is what is required for the seeds to germinate. In the case of parasites producing fine seeds in large numbers, the seeds do not germinate except under some special circumstances. Nearness to the host plant seems to be an essential condition for germination. The exact manner in which the host influences the seed is unknown. It is this striking peculiarity of the seed that enables plants like Striga and Orobanche to become serious pests. The seeds are hardy and remain dormant, until they come in contact with appropriate hosts.

The group of plants called fungi are entirely lacking in chlorophyll and, therefore, they have to obtain everything they want either from other animals or plants. Many of the fungi are parasites and they are responsible for most of the deadly diseases of cultivated plants. The rust, the smut and the mildew which destroy crops wholesale are all fungi. Several fungi obtain what they want from the debris of dead animals and plants, and they are called **saprophytes**.

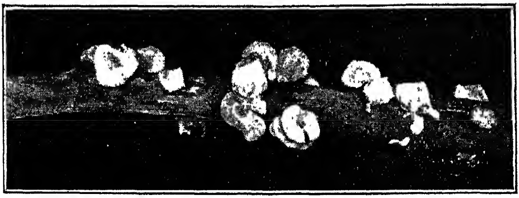


FIG. 216. A saprophytic fungus.

In many ways the fungi are one of the most remarkable groups of plants. Though the vegetative parts of fungi are very simple, their power of adaptation to varying conditions and the way they affect their hosts are things to be wondered at. Some fungi become associated with the roots of certain plants and such roots are called **mycorrhiza**. These roots are devoid of root-hairs and, instead, have a fine covering of fungal hyphæ. The fungus undoubtedly gets carbohydrates from the root and the work of absorbing water is done by the fungus.

There is also a very close association between a fungus and an alga (a lowly organized plant with chlorophyll) in what are called lichens. The alga prepares the carbohydrate material for its own use as well as for the use of the fungus and the fungus absorbs water and salts. (See fig. 217.)

There is yet one more method of nutrition observable in some plants to which we should now turn our attention. Plants usually obtain the nitrogenous substances they require, by the usual method of proteid assimilation. But some plants do not seem to be able to get enough of these substances and so they have adopted a novel method of

supplementing their supply. By special adaptations these plants are able to catch small insects and make use of the nitrogenous stuff contained in them. As examples of such plants we may mention the species of Drosera and Utricularia flourishing in this Presidency. In swampy situations, all over

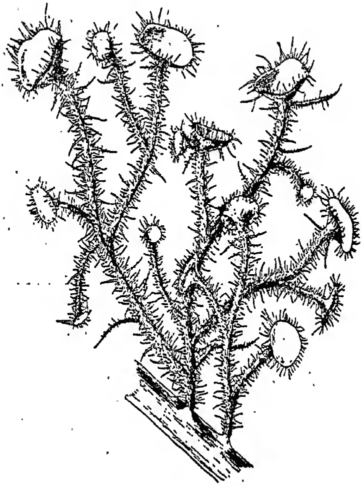


FIG. 217. Lichen (*Usnea barbata*).

the Presidency, we meet with a tiny plant with small rosettes of leaves appressed to the ground. From amidst the leaves rises, the inflorescence, which is a false raceme with white flowers. This is *Drosera Burmanni.* The leaves are somewhat rounded with a short narrow stalk. The whole upper surface of the blade is beset with bristle-like hairs ending in glandular tips. These hairs are reddish and are always secreting at their free ends a clear, sticky liquid. When an insect happens to become entangled amidst these glandular hairs, all the hairs curve inward and the sticky juice is secreted in abundance and the prey is ultimately digested. In another species *D. indica* the leaves are linear and in other respects it is the same as *D. Burmanni.* (See figs. 175 and 176.)

In Utricularia we have another set of plants that capture small animals and make use of them as food. These plants flourish in marshes and in the edges of ponds and in wet

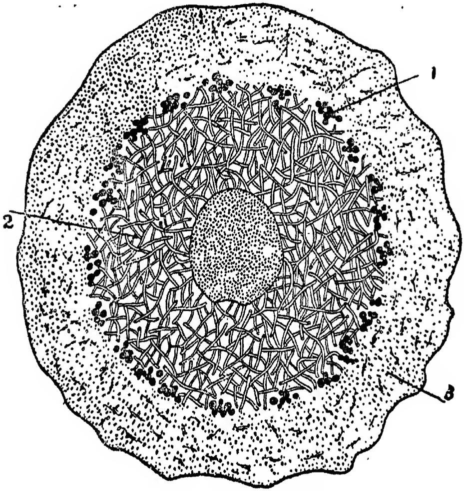


FIG. 218. A transverse section through the filament of Usnea, highly magnified. 1, algal cells; 2, fungal hypha: 3, compact fungal hyphœ.

places generally. The leaves are modified into special bladder-like structures with trap-doors to capture small insects as prey. (See fig. 178.) The most common species are *U. Wallichiana* and *U. reticulata.*

Plants of the family Leguminosæ and a few other plants are rather peculiar in the mode of obtaining their nitrogenous food. If the soil in which these plants are grown contains enough nitrates, the plants are able to make the protein food in the usual manner like other green plants. Even if the soil happens to be poor in nitrates these plants manage to get the protein food all right. The roots of these plants have tubercles or nodules full of bacterial mass, consisting mainly of large abnormally developed bacteria called "bacterioids"

and of bacteria in the normal condition, and these nodules vary in size and shape according to the species of the plant. (See fig. 219.) In fact these bacterial nodules are formed as a result of the invasion of the bacteria. Gaining entrance into the root hairs these bacteria get into the cells of the cortex and stimulate them to grow larger and develope into nodules.

Between the leguminous plant and the bacteria there is some peculiar relationship in the matter of nutrition. Here we have a case of mutual parasitism. The bacteria live on carbohydrates supplied by the host plant, while the latter makes use of the protein food prepared by the bacteria by taking in the free nitrogen of the air. So long as the bacteria are alive the host plant gets a steady supply of nitrogenous substance, and ultimately the remaining substance of the degenerated bacterioids is also absorbed.

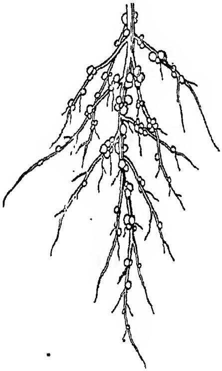


FIG. 219. Bacterial nodules in the root of a Leguminous plant.

By reason of this peculiar mutualism leguminous crops can be grown in soils which contain no combined nitrogen whatever, provided the proper bacteria are present. This is the reason why leguminous plants are considered important in enriching the soil.

Besides these there are certain bacteria living quite independently in the soil that are capable of fixing free nitrogen. This property is of the greatest importance in agriculture, because there will be accumulation of nitrogenous substances in the soil which become available for other plants that happen to grow in that soil. Some low fungi also are believed to have the property of fixing free nitrogen.

CHAPTER XIV

GROWTH AND MOVEMENT IN PLANTS

LARGE quantities of food material are produced by a green plant. But it utilizes for its growth only a small part of it. The remaining portion is stored in places such as roots, stems, fruits and seeds. The manufacture of organic substances is to help the growth of the plant, and growth means increase of organs in size and number. Growth and formation of food may go on for any length of time under favourable conditions. Once a plant starts life, it may go on living for any length of time, so that the same individual continues to live. Consider the case of such a tree as the Banyan which is capable of growing for a long time unceasingly and covering many acres of land by gradual extension, if left undisturbed. It produces adventitious roots from branches, and these get into the soil and support the branches and also absorb water containing salts. As examples of trees thus extending we may mention two Banyan trees in this Presidency, one in the neighbourhood of Madura town and the other near the village Jakkeri, in Hosur taluk.

A plant assimilates the food it prepares and transforms it into cells, and formation of new cells leads to the process of growth. The processes of nutrition and growth are independent. They do not take place at the same time, and in the same place. Growth is active in the younger parts of plants, and the fully developed organs alone are concerned in the work of nutrition. In plants growth is localized and it can go on unchecked so long as conditions are favourable. But in animals it is not localized and it ceases after a certain stage.

By growth we mean increase in bulk, and it must not be forgotten that it is not necessarily due to addition of new matter. For instance, during germination the growing seedling will show loss of material, instead of gain in weight. Increase of bulk in the case of growth is brought about by the addition of new cells and their subsequent expansion.

Growth really consists of three distinct processes, viz., the formation of cells by cell division, elongation of cells and their differentiation. The division of cells takes place at the extreme tip, and the other two processes take place in the region lying behind the actual tip. It must not be supposed that these three regions are quite distinct, one region passes into the other insensibly. At the actual tip the formation of cells is the most prominent feature, and in the part behind it, elongation is the chief feature, though differentiation may be going on in certain cells.

The formative or the embryonic phase.—All plants begin their existence as a single cell, for it is really the fertilized egg-cell that divides and developes into the embryo. All the cells in the embryo are in the formative stage so long as it is within the seed. But as soon as germination begins, only those cells at the extreme end of the plumule and the radicle remain in the formative or embryonic phase, whilst the cells between these grow larger and longer. Therefore in a higher plant the growing points of shoots and roots alone consist of embryonic cells. We have already described the nature of these formative cells as meristem tissue (see page 152). The cells of this tissue are characterized by the possession of a relatively large nucleus, very thin and delicate cell-wall and compact cytoplasm with very minute vacuoles or without them (see figs. 191 to 193).

Formation of new organs at the growing point.—Branches and leaves arise as small structures at first, at the growing point in regular succession. In fact, all new organs in the shoot are produced at the surface in the primary meristem of the growing points, the first indication of such organs being a slight elevation of the surface. Some cells at certain definite points in the primary meristem divide and grow more rapidly than the others, causing slight swellings on the surface. Gradually these swellings become more prominent and develop into distinct protuberances.

Some of these grow and develop into leaves, whilst others remain small and become axillary buds. All the organs arising in the shoot-system of a plant have a superficial origin and hence this mode of formation of organs is termed **exogenous**. The formation of lateral roots is different. The

growing point of the root merely gives rise to cells which only lead to the elongation of the root. Lateral roots do not arise at the surface in the primary meristem, but originate from the cells of the pericycle which consists of cells that have ceased to divide. The lateral roots break through the cortex and hence these are said to be **endogenous**. Adventitious growing points developing into shoots often arise endogenously on roots and old shoots.

The phase of enlargement and elongation.—At the growing point whilst new cells are constantly produced those already formed begin to change in size, shape and other cha-
The protoplasm in these cells begins to absorb water
and the cells become turgid. The extra amount
absorbed must necessarily put the cell-wall on the
The protoplasm inside the cell, being always active
adds to the cell-wall so that it retains permanently the size it gets under pressure. Once again the cell-wall will be stretched and there will be addition of material leading to the further growth of the cell-wall. This process of the stretching of the cell-wall and growth of it in extent will be going on until the cells attain their permanent forms.

The most striking change in the second phase of the growth of the cells is the enormous enlargement taking place in their size, which increase may be a hundred fold or more. Another notable feature is that the space within the cell-wall arising on account of the rapid increase of the area of the cell-wall is occupied mostly by water.

No doubt the protoplasm also increases in quantity to a considerable extent but much the greater part of the cell is occupied by water. As described above water enters the cells because of the presence of osmotic substances and makes them turgid. At first the minute vacuoles are enlarged and, as absorption of water proceeds, these vacuoles become still larger and finally only one large vacuole may exist reducing the protoplasm to a primordial layer. It is indeed remarkable that plants attain the chief part of their enlargement, by means of water, thus dispensing with the necessity of using very large quantities of food substance which would be necessary, if the enlargement were to be brought about by increase in the amount of protoplasm.

The cells in the embryonic stage have all the three dimensions more or less equal. Enlargement takes place in all directions, but not equally. Cells in some place may grow more rapidly in length than in their breadth, while others may increase more in the transverse direction. The process of elongation of any part is really the elongation of the cells constituting that part.

The growth and elongation of parts in plants is generally so slow that it is imperceptible. But in some plants it is so rapid as to be visible even to the naked eye. The stamens of grasses grow very rapidly in length. For example it has been observed that the stamens of wheat grow in length at the rate of 1·8 mm. per minute. When the aerial stems of the plantain (Musa) are cut across, we see within five minutes the young leafstalk and the convolute blade rising above the level to about 1/5 to 1/4 inch, i.e., an elongation of about 1·2 mm. per minute. If the elongation of any part is carefully observed, it would be seen that the rate of growth in length is slow at first, then rapid until the maximum rate is reached, then slow and finally ceasing to grow.

The growth in length of a plant may be found out by means of an auxonometer. A very simple form of this apparatus is shown in fig. 220.

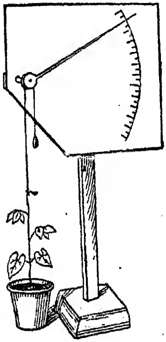


FIG. 220. A simple auxonometer.

The elongation is magnified many times and so it is easily observed. The long arm of the pulley should be at least twenty five to thirty times the shorter arm. Then the rapidity of the growth would be magnified twenty-five to thirty times. By the use of auxonometer we can measure only the total elongation. The manner of using this apparatus can be inferred from the figure. Inasmuch as all the cells of an elongating organ do not grow equally, it is obvious that certain zones would show greater elongation than others.

The distribution of growth, for example in an young shoot or a root, may easily be determined by measuring the distance between marks made on them at equal intervals. Marks of one millimeter spaces were made with water proof Indian ink on the radicles of the seedlings of Cicer and Canavalia and the results were as shown below :—

1. Cicer : marked into 10 divisions, one mm. each.
   after 24 hours :—1 to 8th divisions no change; 9th 3 mm. and 10th 7 mm.
   after 48 hours :—1 to 8th divisions no change, 9th 5 mm. and 10th 15 mm.
2. Canavalia : marked into 8 divisions, one mm. each.
   after 24 hours :—No change in divisions, 1, 2 and 4, 3rd, 5th and 6th 2 mm. each, 7th 3 mm. and 8th 8 mm.

Conditions for growth.—An adequate supply of water is essential, because both divisions of cells in the meristem and their further enlargement are dependent upon the turgidity of the cells. Constructive material also must be available in sufficient quantities. Access of oxygen to these cells is another necessary condition. In the absence of oxygen cell-division cannot go on. Therefore, even in the meristem tissue we find intercellular spaces (see fig. 191). As a rule plant growth is retarded by light, whilst in feeble light and darkness it is accelerated.

Movements in plants.—A plant has different kinds of work to do. If it is to perform all its functions properly, it must possess not only the power of placing all its organs in the position most appropriate for the due performance of their functions, but they should also have the power of responding in a suitable manner, when changes occur in external conditions. All the organs must be arranged to their best advantage. For instance, the foliage leaves must be so held as to enable all the leaves to obtain sufficient light and the roots have to get into the soil and there branch in an adequate manner.

The factors, influencing the organs of a plant are gravity, moisture and light. The main root of a plant goes vertically downward in response to the stimulus of gravity. For the

tap-root this is the position of rest or equilibrium, and the same stimulus has a different directive influence on the lateral roots ; these take a horizontal course. The shoot also is subjected to the influence of gravity, but its position of rest is different from that of the root. It goes straight up against gravitation. Any disturbance in the equilibrium in the root, or in the shoot causes the part disturbed to make a curvature which will enable the member to assume the position of rest.

Movements exhibited by plants, in response to stimuli are due to the property of irritability possessed by protoplasm. Protoplasm is able to respond to stimuli of different sorts, and irritability is one of the fundamental properties of the protoplasm.

The roots have the power of responding to both moisture and gravity. When a root is disturbed by any change in its position of rest, it readily responds by means of growth curvatures, and the movements causing the curvatures are called **trophic movements.** For instance, a seedling having a well developed tap-root when placed in a horizontal position will show a curvature a little above the growing tip and the root-tip will assume the vertically downward direction. This movement of the root in response to the influence of gravity is called **positive geotropism.** As growth in length chiefly takes place just behind the root-tip, the growth curvature is seen in this region. It should also be remembered that the root-tip alone is sensitive to the stimulus of gravity. The tap-root of a seedling is not affected by gravity when the actual growing tip is cut off. However, when a new growing point is formed, the root responds. From this it is clear that the root-tip alone is sensitive. The shoot also under similar circumstances responds to the stimulus of gravity by means of a growth curvature just behind the actual growing tip. But the direction of the curvature in this case is quite opposite to that of the root, and hence the shoot is said to be **negatively geotropic.** This difference in behaviour, although the stimulus is the same, is probably due to the difference in structure between these two organs.

The fact that the root and the stem are made to grow as they do by the influence of gravity may be demonstrated by

means of a special apparatus, called the Klinostat. The apparatus is only a clock-work arrangement which rotates an axis bearing a plate at its free end. The axis can be made to be horizontal in position. In this position of the axis the plate must necessarily rotate in the vertical direction. If we fix to this rotating plate, seedlings in different directions, no curvatures are seen either in the root or the shoot. This is because the seedling is exposed on all sides equally to the influence of gravity. So there is no curvature. This method is adopted as it is impossible otherwise to prevent the action of gravitation.

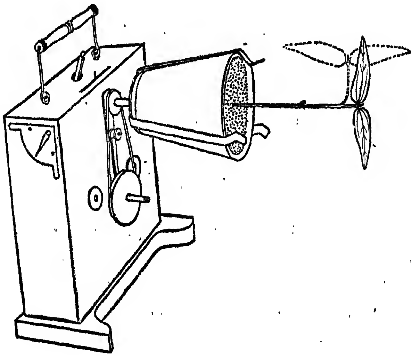


Fig. 221. Klinostat. The dotted line denotes the position the leaves and the axis at the top would occupy when the Klinostat is not set going.

The response of the root to the stimulus of moisture is called **hydrotropism**. One may probably be led to wonder as to why the root should be influenced in this manner by gravity and moisture. If we remember the functions that a root has to perform, it becomes obvious that it is necessary for the root to be so affected by these two factors. The great need of the root-system is to explore the soil thoroughly and to come in contact with as much soil as possible, in order to do its work efficiently.

The tap-root has generally a tendency to grow vertically downwards. But it will not do so under all circumstances.

Sometimes, for the sake of moisture, it will move against the force of gravity. If in a large seedling-pan filled with saw-dust or sand, we place in the centre a flower-pot filled with water and plant seeds around it outside and allow them to sprout and grow into seedlings, we shall find all the roots turned towards the pot containing water. In the case of epiphytes the aerial roots sometimes grow straight up for the sake of attaching themselves to branches lying above them.

As green plants require light for doing their work, we should expect them to respond to the stimulus of light also. When a plant is placed near a window, the shoot invariably curves over towards it because of the one-sided illumination. When a plant fixed to the plate of a Klinostat in motion, is placed near a window, the stem does not curve towards the window, but grows erect. In this case the plant receives equal illumination on all sides. A *Dolichos Lablab* seedling placed near a window showed the curvature within twenty minutes. Plants growing in open places grow straight, for they are equally illuminated on all sides. In a shoot bending towards light, the axis lies in the direction of the light rays, whereas the leaves are either at right angles, or oblique. So the axis of the shoot is positively phototropic and the leaves are diaphototropic or transversely heliotropic. This conclusively proves the fact, that the same stimulus does not necessarily produce the same kind of response in all the organs of a plant. As a matter of fact, the response is dependent upon the character of the organs concerned, as well as upon the nature of the stimulus. Aerial roots and tendrils of certain plants turn away from light.

Roots of plants are, as a rule, negatively heliotropic. Sometimes seedlings of mustard when grown in water as in water-culture experiments are highly sensitive to light. The shoot is positively heliotropic and the root negatively so.

In the case of all curvatures the actual bending takes place only in the region of maximum elongation, but the power of perception belongs to the younger parts above it.

We should not omit the movements exhibited by protoplasm within the cells. In the epidermal hairs of Cucurbitaceous plants the protoplasm inside the cells shows a kind

of movement which is called **circulation**. The protoplasm within the epidermal hair-cell consists of a layer adhering to the cell-wall and a number of slender protoplasmic threads and they are in different directions. There is another kind of movement in which the protoplasm moves along the cell-wall in one direction only in a cell, carrying with it the nucleus and the chlorophyll grains. This movement is called **rotation**. The direction of movement will be different in different cells, but inside the same cell the movement will be in one direction only. In one cell the motion may be from right to left and in a second cell it may be from left to right and so on.

CHAPTER XV

INFLORESCENCE

We have already examined as types the Tribulus and Gynandropsis plants. In the former the flowers are borne singly in the axils. Judging from the position, we have to conclude that the flower is really a branch bearing floral leaves, instead of foliage leaves. In *Gynandropsis pentaphylla* the flowers spring from the axils of leaves, but they are all gathered together towards the extremities of branches. The leaves from whose axils flowers grow out do not differ very much from the ordinary leaves in this plant, except that they are small. But leaves thus associated with flowers are generally small and differ very much from the foliage leaves. Such leaves are termed **bracts.** The flower bearing axis in Gynandropsis grows steadily upwards producing flowers one after another in regular succession; and so the oldest flowers are below, i.e., further away from the apex of the axis and the order of the opening of the flowers is from the base upward towards the apex **(acropetal succession).**

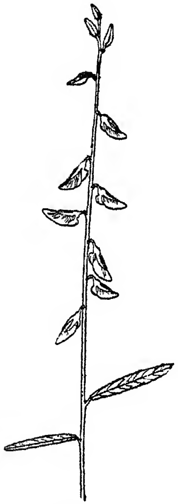


Fig. 222. Raceme of Crotalaria.

A collection of flowers on an axis is called an **inflorescence.** There is considerable amount of variation in the matter of

the arrangement of flowers, and so we have different kinds of inflorescence. An inflorescence similar to that of Gynandropsis, i.e., one in which a number of stalked flowers are borne by an elongated axis in acropetal succession, is called a **raceme**. There are many plants having this kind of inflorescence, and as examples we may mention those of Crotalaria, *Sesbania ægyptiaca*, Cleome and Tephrosias. In all these plants the flower-stalks are, more or less, of the same length. In the terminal younger part of the inflorescence of Gynandropsis the pedicels of the lower flowers are longer than those above and as a consequence all the flowers are on the same level. This kind of inflorescence is called a **corymb.** (A cymose inflorescence also is sometimes corymbose.)

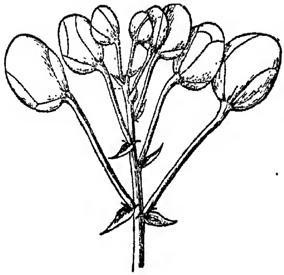


Fig. 223. Corymb of Cassia.

Examples of corymbs may be seen in Cassia, Cæsalpinia and Ixora.

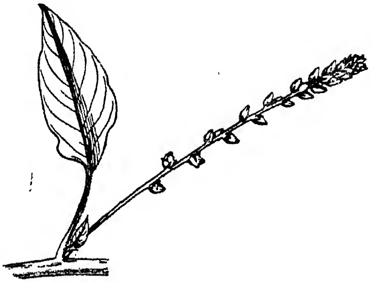


Fig. 224. Spike of Digera.

Flowers are not always stalked. They may be sessile on the axis as in the inflorescence of *Achyranthes aspera*.

Compared with the raceme this differs from it in only one respect, namely, the absence of pedicels. Such inflorescences as these are called **spikes**. As further examples of spikes we may mention the inflorescences of Amarantus, Digera and Celosia. Sometimes the axis of the spike becomes fleshy and a large sheath or bract also becomes associated with it, as in the case of the inflorescence of Colocasia or Amorphophallus. Then the inflorescence is termed **spadix**, the sheath being called a **spathe**.

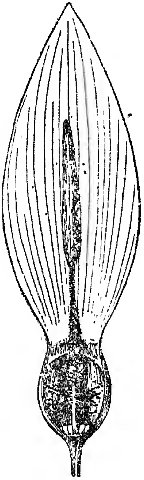


FIG. 225. Spadix and spathe of an Aroid.

Very often the stalked flowers, instead of springing from the axis at different heights, arise from the summit of the main axis, and this is called an **umbel**. The inflorescences in onion, coriander, Tylophora and Pentatropis are all umbels. If we imagine the flowers of an umbel to be sessile, instead of being stalked, we have an inflorescence termed a **head** or **capitulum**. The summit of the peduncle becomes enlarged, in this case, so as to afford room for the sessile flowers. The so-called flowers of the Sunflower plant, of Tridax and of Vernonia are all heads.

FIG. 226. Simple Umbel of *Calotropis gigantea*.

The raceme, spike, umbel and head have the flowers in the same succession. The oldest flower is at the base and the youngest is at the top of the axis. Further, the axis is a

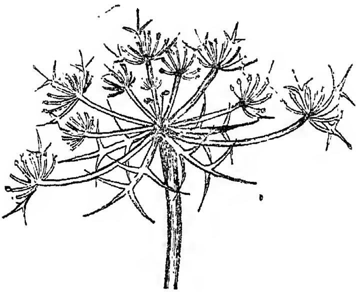


FIG. 227. Compound Umbel.

monopode. So these may be considered as forming a type of inflorescence, and the type is called **racemose** or **botryose.**

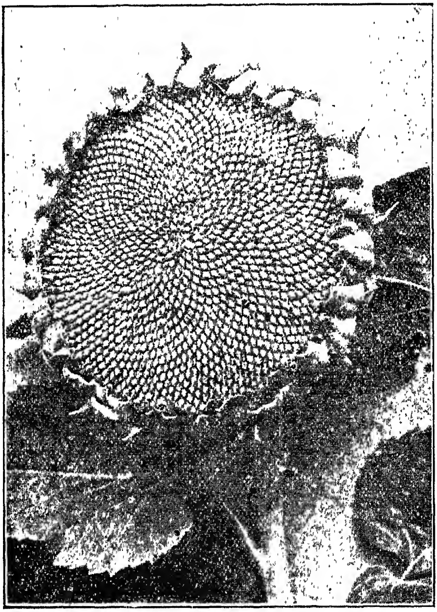


FIG. 228. Head of the Sunflower plant.

It is also called **centripetal** because the order of blossoming of the flowers is from the circumference of a circle to its centre ; another term sometimes used is **indefinite.**

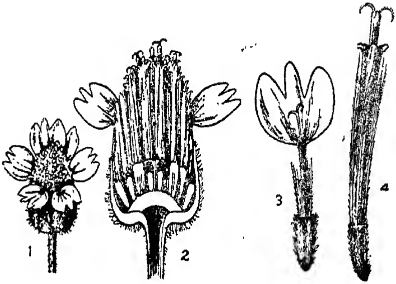


FIG. 229. Flower head of Tridax. 1, entire head ; 2, head cut vertically ; 3, ligulate flower ; 4, tubular flower.

In some plants the main axis terminates in a flower which is the first to open. Lateral branches arise later from below and they also end in flowers. The inflorescence in the ordinary Jasmine plant is of this kind. It consists of an old

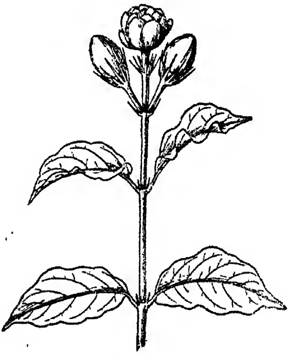


FIG. 230. A simple cyme of the Jasmine plant.

flower in the centre and two young flowers laterally, one on each side. This kind of inflorescence is quite distinct from the botryose type and so it is called **cymose.** As the order of flowering in this type is from the apex to the base **(basipetal),**

the inflorescence is described as **centrifugal.** It is also called **definite.**

In the cymose type of inflorescence also there are certain variations deserving notice. The three flowers forming an inflorescence in Jasmine may be termed a simple cyme. A simple cyme of this sort becomes modified in many plants. The lateral branches, in their turn, give rise to lateral flowers, one on each side. Then, instead of a simple cyme, we get an older flower with two simple cymes on the two sides. Such inflorescences as these are met with in several species of Ipomœa, Clerodendron, etc. This kind of increase is in some cases repeated indefinitely, as in the case of Nerium and Wrightia. If the development of the lateral branches is regular the inflorescence is called a **dichasium.**

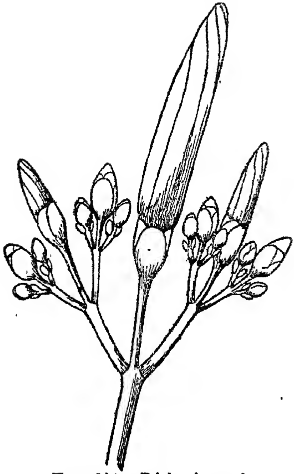


FIG. 231. Dichasium of *Ipomœa carnea.*

Irregularity, in the development of the lateral branches in the cymose type of inflorescence, is not uncommon. Instead of having lateral flowers on both the sides, the central flower may have only one, on one of its sides. If the suppression of the lateral flower is confined regularly to the same side, as in some Solanums, we get what is called a **helicoid cyme.** If, on the other hand, the suppression takes place alternately first on the right side and then on the left regularly, as is seen in the Heliotropiums,

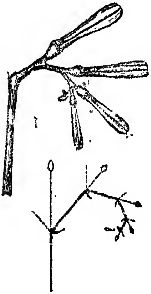


FIG. 232. Helicoid cyme. 1, helicoid cyme of Hamelia; 2 diagram showin suppressio same side.

the cyme is termed **scorpioid**. In both these varieties the axis becomes straight later, though in the young stage it is coiled at the free end, and it is a sympode. The helicoid cyme may be mistaken for a raceme with flowers all on one side. But as the axis is really a sympode the arrangement of the bracts will be quite different. In the case of the helicoid cyme the bracts when present will be opposite to the flower, and in the case of the scorpioid cymes there will be two rows of bracts, if present.

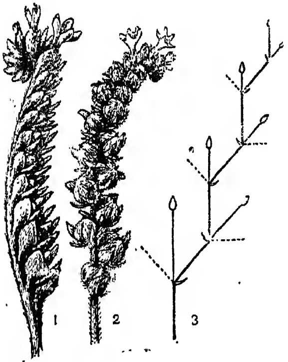


FIG. 233. Scorpioid cyme of *Heliotropium ovalifolium*. 1, side and 2, front view : 3, diagram to show the alternate suppression of lateral flowers.

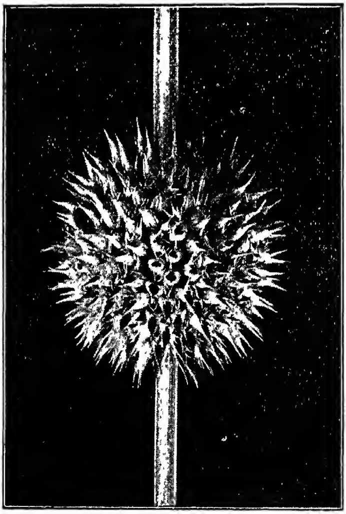


FIG. 234. Verticillaster of *Leonotis nepetæfolia*. (Slightly reduced.)

Sometimes two cymes spring at the nodes opposite to one another as in Ocimum and some other genera of the same family. In some cases, as in Leucas and Leonotis the cymes become condensed and overlap the axis and look like a whorl of flowers; so this is called a **false whorl** *or* **a verticillaster.**

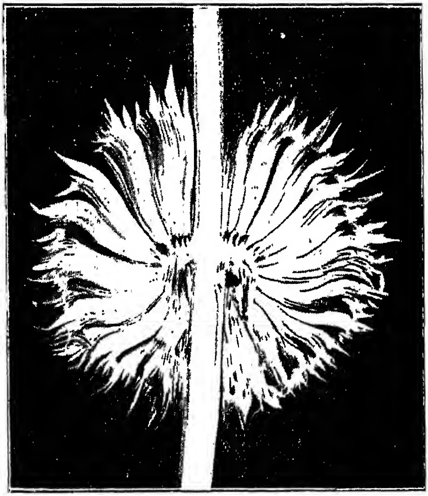


FIG. 235. Verticillaster of *Leonotis nepetæfolia* cut through to show the cymose nature of the inflorescence.

The main kinds of inflorescences and their modifications may be tabulated as follows :—

A. **The Racemose type.**—In this type the rachis gives rise to flowers in acropetal succession, i.e., the young flowers are at the top and the old ones at the base of the axis. This is also called **centripetal or indefinite** :—

(1) **Raceme.**—pedicelled flowers borne by an elongated axis from the base upwards in acropetal succession.

(2) **Corymb.**—A raceme in which the pedicels of the lower flowers are longer than those of the upper.

(3) **Umbel.**—pedicelled flowers all springing from the top of the axis.

(4) **Spike.**—sessile flowers borne by an elongated axis from base upward.

(5) **Capitulum.**—sessile flowers on the summit of the main axis which becomes enlarged.

All these inflorescences are of the simple type. We have also compound forms :—

(1) **Compound raceme.**—The main axis, instead of bearing stalked flowers, has racemes.

(2) **Compound umbel.**—The peduncle bears umbels instead of single flowers.

(3) **Compound spikes.**—Simple spikes arranged on an elongated axis.

(4) **Panicle.**—Any inflorescence with a loosely branched appearance, whether the branching be racemose or cymose or both.

B. **The Cymose type.**—In this type the primary axis or the rachis ends in a flower and then produces immediately below the first flower lateral axes either terminating in a flower or behaving like the main one by further branching.

(1) **Simple Cyme.**—The axis bears three flowers, the central one being the oldest.

(2) **Dichasium.**—The axis terminates in a flower and then produces a pair of lateral branches bearing cymes that are simple or they may also become branched further by repeated divisions.

(3) **Monochasium.**—An elongated sympodial axis bearing flowers, the bracts being opposite the flowers. There are two varieties of monochasium :—

(*a*) **Helicoid.**—The lateral branches develop on only one side in a regular manner, and the other one being regularly suppressed on the other side.

(*b*) **Scorpioid.**—The suppression of the lateral branch is alternate, i.e., the right one is suppressed and then the left and again the right and so on.

(4) **Verticillaster.**—Axillary cymes very much congested and surrounding the stem.

CHAPTER XVI

THE FLOWER

A FLOWER is a short shoot appearing only periodically on a plant with longer or shorter intervals. In plants we find leaves and leafy shoots always, but not flowers. This is so on account of the difference in their function. Leaves and other vegetative organs are concerned in the work of nutrition, a process going on continuously. On the other hand, flowers are the organs intended for the propagation of plants, through the seeds; and propagation is not one of the processes going on continuously in a plant. So we do not find flowers always. Large quantities of food material are needed for the formation of flowers and this is why a young plant does not produce flowers. A period of vegetative activity must necessarily precede the formation of flowers, otherwise large accumulations of food material are not possible. In corms and bulbs large amount of food is stored and therefore they give rise to flowers when planted.

From a study of the *Tribulus terrestris* flower we have learnt that a flower consists essentially of an axis carrying sepals, petals, stamens and the pistil. The first two, sepals and petals, are only accessory organs forming the **perianth** of the flower. The remaining two sets of organs form the essential organs of the flower. This flower is a complete one because it has all the four sets of the floral organs. Both the essential organs of the flower exist together and so the flower is **bisexual** or **hermaphrodite.**

Let us now look at the arrangement and the insertion of the various parts in the flower. All the parts are attached to the free-end of the flower-stalk in a definite order. The apex of the stalk, or the **receptacle**, as it is called, is surmounted by the pistil and the other whorls are below this. The pistil is therefore said to be superior, and the other parts inferior.

The parts of the outermost whorl or sepals alternate with the petals. There are two whorls of stamens, the inner being

opposed to the petals and the outer to the sepals. The carpels in the innermost whorl alternate with the second or the inner whorl of stamens. There are five protuber-

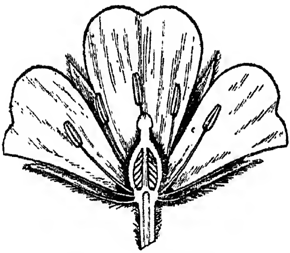


FIG. 236. A longitudinal section of a flower of Tribulus showing the attachment of the parts.

nected with the shorter stamens. These are called **glands**.

The Tribulus flower possesses five whorls and each of these consists of five members. Further, the flower can be cut into two symmetrical halves through any plane. So it is a typical, regular, symmetrical flower.

A transverse section through a young bud will reveal the general arrangement of the various parts. It is usual to

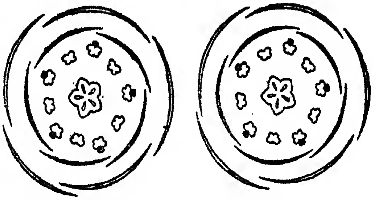


FIG. 237. Floral diagram of Tribulus.

represent such sections diagramatically, and they are called floral diagrams. For showing in a clear manner the positions of the parts, it is a convenient method. Circles corresponding in number to the whorls are drawn concentrically and on them the positions, as well as the union of the parts of each whorl, are marked. The position of the main axis bearing the flower and that of the bract are also usually represented in the diagram. The floral diagram of Tribulus is represented in fig. 237. Out of the five sepals, two have both their margins outside, two have them inside and one has a margin inside and the other outside. One petal has both the margins outside, another has both its margins inside, and the remaining three

petals have one margin in and the other out. In some flowers petals are contorted.

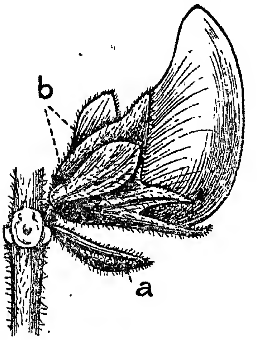


FIG. 238. Bract and bracteoles in the flower of *Dolichos Lablab.* a, bract; b, bracteoles.

Flowers that are solitary usually arise from the axils of leaves. But in the case of flowers that are clustered together so as to form inflorescences, the individual flowers spring from the axils of very small scale-like structures and not from the axils of foliage leaves. These small structures are **bracts.** There are also instances in which the bracts are wanting, as in the case of Mustard and Cleome. Very often, we meet with plants whose flowers bear, in addition to the bract, two small additional scale-like structures. These are called **bracteoles.** The flowers of *Dolichos Lablab* and *Clitoria Ternatea* have both bracts and bracteoles. We have also instances of flowers having more than two bracteoles, in the flowers of Hibiscus, Pavonia and Cotton. There is yet one more variation in the bract already referred to in the last chapter and this should not be passed by. The whole of the inflorescence in certain Aroids and palms is enclosed completely, by a large sheath and it is termed a **spathe.** It is not uncommon to have more than one spathe in the inflorescence, for instance there are many spathes in the spadices of Musa.

We find endless variations in the structure of flowers, and so it is necessary to examine the flowers of a few more plants. We may study the flowers of *Dolichos Lablab*, Crotalaria, any Hibiscus, Ipomœa, *Ruellia prostrata*, *Allium Cepa*, *Crinum asiaticum* and *Aristolochia bracteata* with advantage.

The flowers of *Dolichos Lablab* are clustered together so as to form a compound raceme. The flower-stalks of the individual flowers (pedicels) spring from the axils of small bracts and there are also two bracteoles, one on each side of the calyx. The outermost whorl of the flower the calyx, is in

the form of a cup, but five divisions may be made out in it, showing that it consists of five sepals ; in such cases as these,

Fig. 239. A spathe and spadix of the Coconut palm.

the calyx is described as **gamo-** or **mono-sepalous.** Of petals there are five, and they are not all alike ; one petal is larger than the others and it is the outermost in the bud. In an open flower this petal stands upright and is generally very conspicuous, and it is called the **standard.** On the sides of the standard and below are two petals and these are called **alae** or **wings.** Next to these come two narrow petals bent in the middle and cohering so as to resemble a boat, the **keel petals.** Within the keel petals lie the stamens, ten in

number. One stamen alone remains free and the remaining nine are united together by their filaments so as to form a tube slit on one side. Stamens thus united into two bundles are described as **diadelphous.** The anthers are all uniform. The pistil consists of an ovary and a style bent in the middle so as to correspond with the bending of the keel petals.

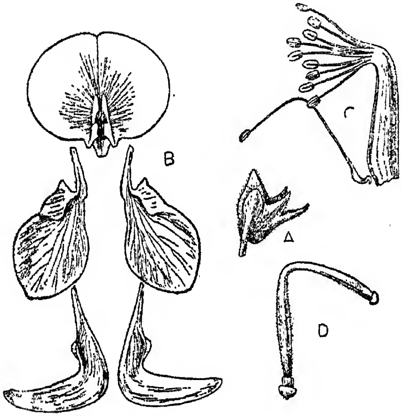


FIG. 240. The floral parts of *Dolichos Lablab.*
A, calyx ; B, petals ; C, stamens ; D, pistil.

The flowers of Crotalaria resemble those of *Dolichos Lablab* in all essential respects. The stamens are in this case in one bundle (**monadelphous**) and the anthers are of two kinds, five elongated and five rounded and short. When the stamens are of two kinds, as in this case they are said to be **dimorphic.**

Of the various species of Hibiscus the commoner ones such as, *Hibiscus esculentus*, *H. vitifolius*, *H. cannabinus* and *H. micranthus* may be examined. In *Hibiscus esculentus* the flowers are solitary and axillary. There are a number of bracteoles forming an epicalyx. The calyx is tubular and it opens on one side to allow the petals to come out. There are five petals free, except at the very base, where they are attached to the staminal column. The stamens form a

tube, i.e., they are monadelphous. All the anthers are borne by short threads disposed along the outside of the tube. An anther usually consists of two lobes, but in this flower it has only one lobe. Within the staminal tube lies the pistil, which consists of a dilated portion, the ovary, a thin thread-like part, the style, terminating in five branches bearing the stigmas.

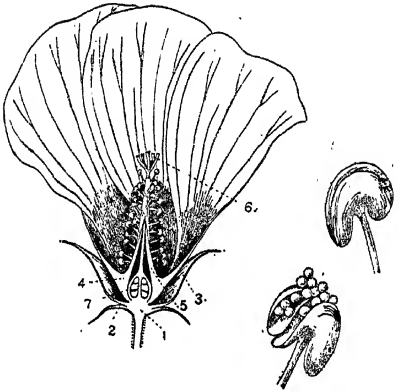


FIG. 241. The floral parts of *Hibiscus vitifolius*. 1, receptacle ; 2, bracteole ; 3, calyx ; 4, base of petal ; 5 staminal tube ; 6, style branches bearing stigmas. Two anthers, one closed and the other open, are also shown.

The flowers of *Hibiscus vitifolius* and *H. cannabinus* are similar to those of *H. esculentus* in all essential respects, but he bracteoles and the calyx are different. The flowers of *H. micranthus* are rather small and the petals are white, whereas those of the species mentioned above are yellow.

The flowers of Cassia are collected together in simple or compound corymbs, and the flowers are bracteate. The sepals and petals are both free and they are very often of the same colour, and the sepals are then said to be **petaloid.** Further, the sepals vary in size in the same flower in several species of Cassia. Stamens are ten and are not all alike ; some are long with well formed anthers and others short with imperfect anthers. The anthers open by means of pores

at the apex. The pistil is like that of *Dolichos Lablab* in essential points.

The flowers of Ipomœa are different from those already described in this chapter. A flower-stalk terminates in a flower, or there may be three flowers borne by the peduncle and then, the middle flower is invariably the oldest. So the

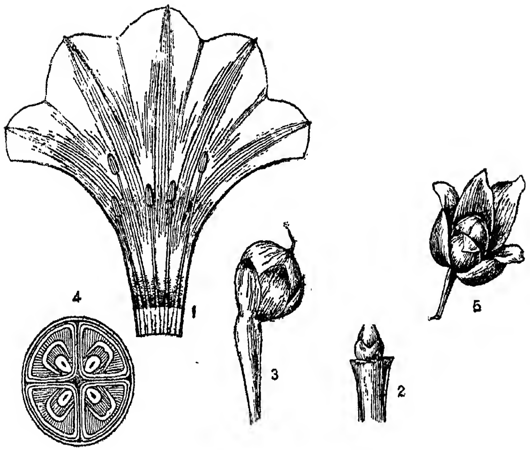


FIG. 242. The floral parts of Ipomœa. 1, corolla laid open with epipetalous stamens ; 2, the pistil ; 3, young fruit ; 4, transverse section of a young fruit ; 5, capsule with persistent quincuncially arranged sepals.

inflorescence is a cyme. In some species it is a dichotomous cyme. The sepals are generally free and their folding is of a particular type called **quincuncial.** Of the five sepals, two are completely outside, two inside and one partly inside and partly outside. The corolla is in one piece and hence called **monopetalous.** It is tubular, funnel-shaped or bell-shaped according to the species. Five lobes can be made out in the corolla. From inside the tube five stamens arise, and so they are said to be **epipetalous.** The pistil consists of an ovary and a thin style terminating in a stigma of two globular bodies. Within the ovary there may be two cells or four.

The flowers of *Ruellia prostrata* are axillary and solitary. The calyx consists of five free sepals and the corolla is tubular and funnel-shaped. There are only four epipetalous stamens, two long and two short. The ovary is two-celled, the style thin and the stigma bifid.

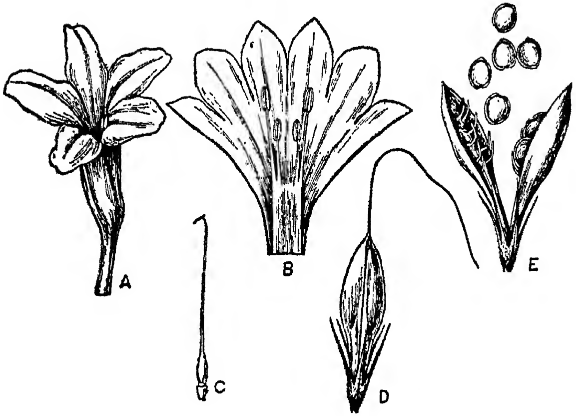
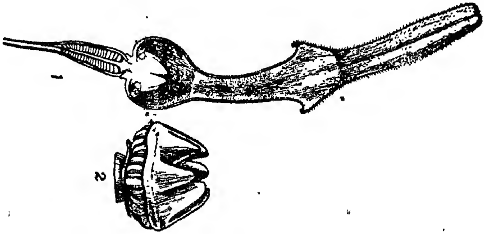


FIG. 243. The flower of Ruellia and its parts. A, corolla; B, corolla laid open with didynamous epipetalous stamens; C, pistil; D, capsule; E, capsule bursting and hurling the seeds.

The flowers so far dealt with are regular and complete ones. The flowers of Achyranthes and Aristolochia are not so. In both, there is only one whorl of perianth, and it is the calyx. The ovary in Aristolochia is inferior and, in Achyranthes, it is superior. The stamens of Achyranthes are five and they alternate with five scale-like structures, called **staminodes**. In Aristolochia the stamens are reduced to their anthers without filaments and they are sunk within a shortened style. The style is very much abbreviated and it is surmounted by a six-lobed stigma. There are six anthers.

There are many plants in which the flowers are **unisexual**, instead of being **bisexual.** The flowers of Gourds and Cucumber plants are unisexual. In *Coccinia indica* the flowers in a plant are all either **staminate** (male), or **pistillate** (female). On the same plant we never find both the

kinds. So the plant is either a male plant or a female one. In such cases as these, the flowers or plants are said to be **diœcious**. If both staminate and pistillate flowers are found



G. 244. The flower of *Aristolochia bracteata.* 1, longitudinal section ; 2, stamens and the style.

on the same plant, as in Cucurbita, Ricinus, Cocos and Acalypha, they are said to be **monœcious**. When bisexual as well as unisexual flowers occur on the same plant they are

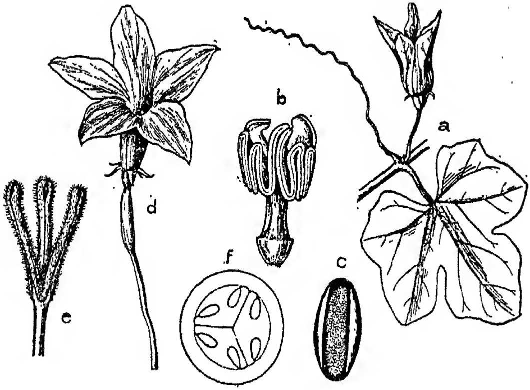


FIG. 245. The unisexual flowers of *Coccinia indica.* a, male flower ; b, the stamens; c, pollen grain highly magnified ; d, female flower ; e, style branches ; f, transverse section of a young fruit.

polygamous. As examples of plants with polygamous flowers we may mention *Carica papaya*, *Cratœva religiosa* and some times *Amarantus spinosus.*

16-A

FIG. 246. Flowers of *Achyranthes aspera.* 1, flowers on the axis; 2, detached flower with bract and bracteoles; 3, pistil.

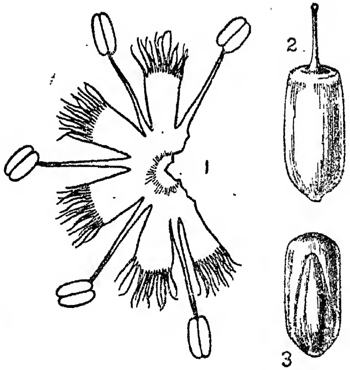


FIG. 247. The floral parts of *Achyranthes aspera.* 1, stamens with staminodes; 2, fruit; 3, seed.

Before dealing with the monocotyledonous flowers, we shall do well to refer to one or more plants having incomplete

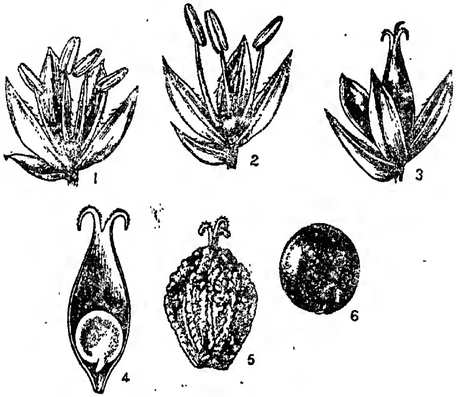


FIG. 248. The floral parts of *Amarantus viridis.* 1, male flower with four perianth lobes; 2, male flower with three perianth lobes; 3 female flower; 4, ovary; 5, fruit; 6, seed.

flowers. In the very widely distributed *Amarantus viridis* the perianth is single, and even this is liable to variation. In most of the male flowers there are three perianth segments, in some four and in rare instances even five. The stamens also vary in number from three to five. In all the female flowers, we find only three perianth segments.

We shall now consider the structure of the flowers of the two monocotyledonous plants *Allium Cepa* and *Crinum asiaticum.*

The flower of Allium or Onion has two whorls of perianth, the calyx and the corolla, both of them being white.

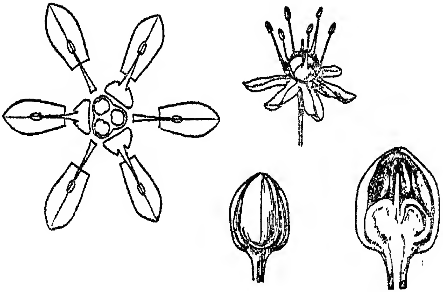


FIG. 249. The floral parts of *Allium Cepa.*

The sepals and the petals alternate with each other and there are three members in each of these whorls. The stamens are in two whorls of three each, and the stamens of the outer whorl are opposite to the sepals and those of the inner to the petals. The ovary is superior and three-celled. The flowers are pedicelled and are in umbels ; but the opening of the flowers is from the centre to the peripheral part of the circumference. So, though the inflorescence is an umbel, it is cymose in character. The flowers of Crinum are also in umbels, and they do not differ very much from the onion flowers in their structure, except that the parts are larger and the ovary is inferior.

From a study of the structure of a few flowers, we clearly see that the parts of a flower are subject to considerable variations. So, it would be instructive to deal with the parts

of the flower, in a general way, noticing only the more striking variations presented by them.

The calyx.—As the main work of the calyx is protection of the other parts of the flower, it is obvious that it should be found in the flowers of all flowering plants, except in cases where the protection is given by some other part. For instance, in the flowers of a head in a Compositæ, such as, Tridax and Vernonia, the bracts forming a sort of envelope to the head do this duty. The flowers of grasses are devoid of calyx, the necessary protection being the work of the very well developed bracts (these are called glumes). The calyx will have done its work, as soon as the flowers open, and so it withers and falls down sooner or later. If the sepals fall off

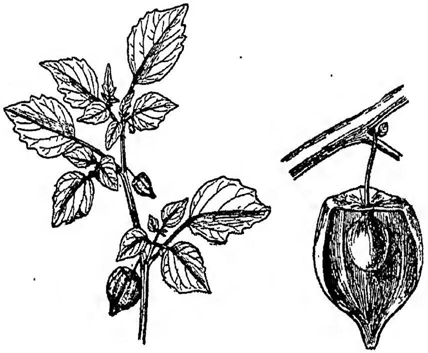


FIG. 250. The large presistent calyx in the flowers of *Physalis minima*. (The branch reduced and the fruit nat. size.)

as soon as the flower opens (as in *Argemone mexicana*), they are said to be **caducous**; when they fall some time after the opening of the flower, they are **deciduous** and, if they remain without falling off, then they are **persistent**. In some cases the calyx is not only persistent, but also grows with the fruit, and not infrequently envelopes it. The Brinjal fruit possesses a persistent calyx growing along with the fruit, but it does not overgrow and enclose it. On the other hand, in the fruits of Physalis and Withania this part is persistent and grows very much more than the fruit and ultimately covers the fruit fully. (accrescent calyx)

In a calyx the sepals may be free, or they may be united. The sepals may be regular and all alike as in Tribulus and Gynandropsis, or they may be irregular as in Cassia, Ipomœa and Cæsalpinia.

The surface of the calyx may have various outgrowths in the form of hairs, scales and glands. In colour this part is green in most plants, although in a few cases they happen to have the colour of the petals; and then the calyx is said to be **petaloid.**

The corolla.—This is the most attractive and beautiful part of the flower and it is also the conspicuous part by reason of its colouration. We meet with greater variations in the corolla than in the calyx. The petals are either free, or united, as in the case of sepals. If the corolla is tubular and widened above as in Datura, it is said to be **funnel-shaped.**

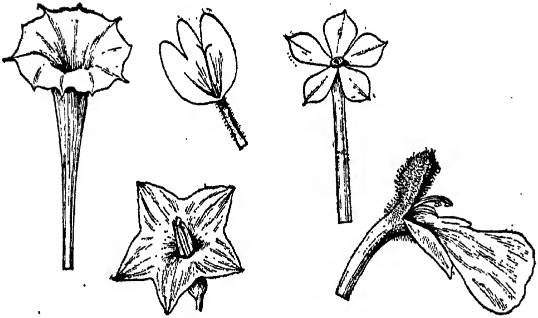


FIG. 251. Corolla and their forms. Funnel-shaped, ligulate, hypocrateriform, rotate and labiate, respectively.

It is described as **hypocrateriform,** when it is tubular with the limbs spreading at right angles. Such a one is seen in *Vinca rosea.* This may also be described as **salver-shaped.** A monopetalous corolla like that of *Solanum Melongena* is **rotate** or **wheel-shaped.** A tubular corolla may have its upper portion divided into two parts, and then it is said to be two lipped or **labiate.**

In the heads of plants of the family Compositæ there are two kinds of flowers; one with a **tubular** corolla in the centre of the head, and all round the margin of the head we

find the other kind with strap-shaped corollas, which are described as **ligulate.**

The petals of a corolla may all be similar in shape and size and then it is regular. In several flowers the corolla is irregular. For instance the petals of Crotalaria and Dolichos flowers are not all alike. Of the five one is larger than the others, and it is called the **standard**; two of the petals are alike and are called the **álae** or **wing petals**; the remaining two together resemble a boat in shape, and, therefore, these are called **keel petals.** A corolla consisting of petals thus modified is called a **papilionaceous** corolla.

There are flowers wherein the corolla possesses outgrowths of various forms. Such outgrowths are known as the **corona.** The flowers of Nerium, Wrightia, and Cardiospermum have coronas in the corolla. Another very good example of a corolla with a corona occurs in Passiflora.

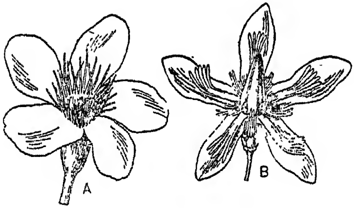


FIG. 252. Corollas with corona. A, flower of Nerium; B, flower of Wrightia.

Before considering the stamens we should deal with the folding of the sepals and the petals in the bud, because the mode of folding is more or less uniform and common to a group or family of plants. For instance, the folding of the petals seen in the flower buds of Crotalaria and Dolichos occurs in all the flowers of plants belonging to the family Papilionaceæ. The petals or sepals just touch each other by their margins without overlapping in some flowers, as in the case of the petals of Calotropis; then they are said to be **valvate.** These, instead of touching by their edges, may overlap each other. For instance, the petals of Hibiscus are as it were twisted, so that one margin of a petal lies above the hinder

margin of the petal in front of it and the edge behind is over-lapped by the front margin of the petal which lies behind it. All the petals are folded thus. This mode of folding is called **contorted** or **twisted**. In this method of folding there is regularity; every petal has one of its edges covered and the other covering. In some flowers this regularity is disturbed by one or more petals getting fully in so that both the margins are inside. Then the mode is **imbricate**. There are several special cases of imbrication and one in which two petals have both their edges outside, two with both their margins inside and one with one margin in and the other out, as in the sepals of Ipomœa and Tribulus, is called **quincuncial**.

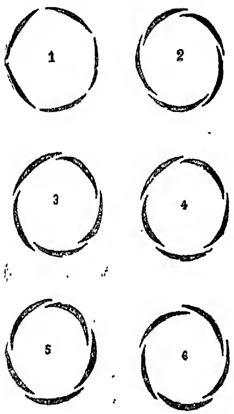


FIG. 253. Aestivation of the floral leaves in the flower bud. 1, valvate; 2 and 6, contorted or twisted; 3 and 5, imbricate; 4, quincuncial.

The Stamens.—The stamens of a flower are also subject to considerable variation. The filaments of the stamens may be free as in Tribulus, or they may become united into one bundle, as in Hibiscus and Abutilon. When the filaments are united in one bundle the stamens are said to be **monadelphous**; if they form two bundles as in Dolichos, then they are **diadelphous**. Occasionally we meet with stamens whose anthers alone are united, the filaments being free. In this case the anthers are said to be **syngenesious**.

Usually the stamens have filaments, but in some cases they are reduced to anthers, as in Orchids and Aristolochia. In both these cases the anthers are attached directly to the pistil, and so the stamens are said to be **gynandrous**.

There is variation in stamens as regards number; they may be many (indefinite), as in the flowers of *Argemone mexicana* or a definite number may be present as in the flowers of Tribulus. The filaments of stamens may all be equal in

length, or there may be variation even in this respect. For instance, in the flowers of the Mustard and Radish plants there are six stamens, four with longer filaments and two with shorter ones. In this case they are said to be **tetradynamous.** In some flowers, as in the case of Justicia, Leucas and Stemodia, there are four stamens two being longer than the other two ; and in this case, the stamens are described as **didynamous.**

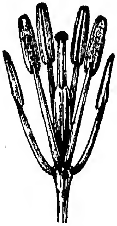


FIG. 254.
Tetradynamous stamens.

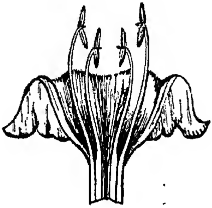


FIG. 255.
Didynamous stamens.

The stamens may spring directly from the receptacle as in Argemone and Tribulus, the ovary being superior ; or they may be attached to the corolla. In the former case the attachment being below the ovary, the stamens are described as

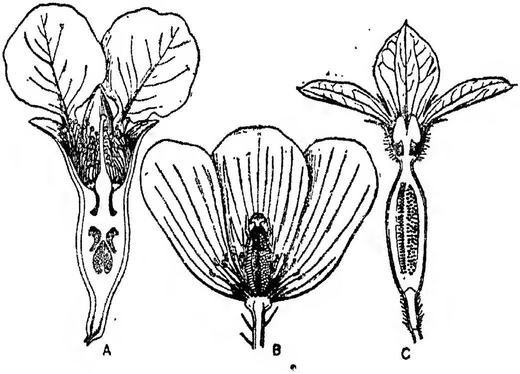


FIG. 256. A, Perigynous ; B, Hypogynous ; C, Epigynous flowers.

hypogynous or **inferior**, and in the case of the latter they are **epipetalous.** We find in some flowers stamens springing, as it

were from the top of the ovary, as in Guava flowers. Then the stamens are said to be **epigynous.** In the pomegranate flower and in the rose flower the stamens are attached to the edge of the receptacle and round the ovary. So the stamens are said to be **perigynous.**

The anthers are attached to the filaments in various ways. An anther attached to the top of the filament at its base is said to be **basifixed** or **innate.** Examples for this are furnished by Cassia. Sometimes the filament becomes prolonged behind the anthers, when the anther is described as **adnate** or **dorsifixed.** In some rare instances as in grasses, the anther is attached to the top of the filament just at a point, so that it moves freely and then the anther is said to be **versatile.** The part of the filament to which the anthers are attached is called the **connective.** This part becomes very conspicuous in some plants by becoming prolonged beyond the anthers, as in Anona, Adenanthera and Trichodesma. The prolongation may also have appendages as in the flowers of Nerium. (See fig. 259.) The close approximation or separation of the lobes of an anther depends upon the development and growth of the connective. When the connective is large and well developed, the anther lobes are far apart. Even with a poorly developed connective the lobes of the anther remain quite separate, and examples for this are afforded by Justicia and Stemodia. In rare instances, as in Ocimum and Salvia, the connective becomes prolonged into two arms, one of these arms remains very short and bears no anther lobe, whereas the other one is long and carries an anther lobe.

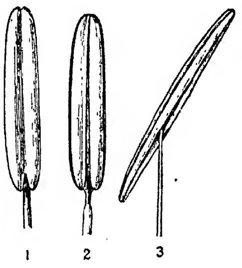


FIG. 257. Stamens showing attachment of anthers. 1, innate or basifixed; 2, adnate or dorsifixed; 3, versatile.

The dehiscence of anthers is also varied. In most cases the anthers open by means of longitudinal slits. Instances for this are seen in Datura and Tribulus. They open by apical pores in Cassias and Solanums. There are also anthers

opening by special lids or valves. Anthers of Mahonia, Berberis and those of the plants belonging to the family Laurineæ are of this sort.

In the case of the dehiscence by a longitudinal slit the face of the anther may be towards the pistil or the petals ; in the former case the anther is said to be **introrse,** i.e., inside, and in the latter **extrorse.**

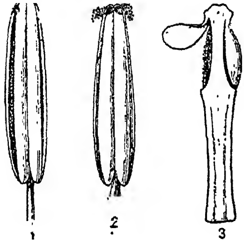


FIG. 258. Dehiscence of anthers. 1, longitudinal ; 2, by apical pore ; 3, valvular.

As in the case of petals, we have in some cases outgrowths from the stamens also. These are called **staminal corona.** We have already referred to the appendages of the connective. They may also arise from filaments as in Calotropis.

The Gynœceum or **the Pistil.**—We have now to deal with the innermost whorl, the pistil, or the female part of the flower. In the Tribulus flower this part consists of a five-celled ovary with a very short style terminating in a five-rayed stigma.

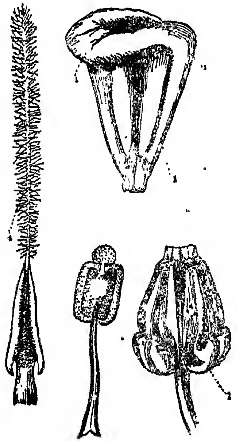


FIG. 259. Appendages of the connective and filament in Nerium, Polyalthia, Adenanthera and Calotropis.

Within the ovary there are five rows of ovules one in each cavity. These rows are attached to a central axis, and the place of attachment of ovules is termed the **placenta.** In Tribulus the placentas are arranged around a central axis, and this arrangement is called **axile placentation.** As further

examples for this kind of placentation, we may mention Ipomœa, Hibiscus and Aristolochia.

In *Gynandropsis pentaphylla* we have an ovary, single-celled, with a short style terminating in a conspicuous stigma. There are three or four placentas on the wall of the ovary, and so the placentation is said to be **parietal.** The ovary of Dolichos also has a single cavity, but with only one placenta. Instances of parietal placentation are found in Argemone, Cucurbita, Modecca and Ionidium. The ovules are also borne sometimes on an axis springing from the base of the ovary. This kind of placentation is termed **free-central**, because the central axis bearing the placentas is quite free and not connected with the wall of the ovary. In Portulaca and Polycarpæa, the placentation is of this kind.

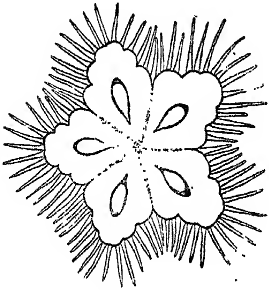


FIG. 260. A transverse section of the ovary of *Tribulus terrestris*.

The ovary is considered to consist of a number of carpels and this corresponds with the number of the cavities in the ovary.

An ovary consisting of only a single carpel, as in Dolichos, Crotalaria and other leguminous plants, is termed a **mono-carpellary** or **simple** ovary; in this case we find only one placenta. In Hibiscus, Tribulus and Aristolochia there are more than one, and so the ovaries in these cases are **compound.** The cavities in the ovary may or may not correspond with the number of carpels. For instance, in the ovary of Gynandropsis, Cucurbita and Portulaca we find only one cavity and yet, in all these cases, the ovary should be considered compound, because of the plurality of the placentas.

All the carpels in an ovary may be united as in Tribulus, and then it is said to be **syncarpous**; on the other hand if they are free as in Polyalthia (see fig. 295), it is **apocarpous.**

For the sake of convenience in description, the part of the placenta bearing the ovules is called the **ventral suture,** the

part opposite to it being termed the **dorsal suture.** In Tribulus, Aristolochia and Hibiscus the narrow portion of the carpel near the central axis is the ventral and the broader back portion is the dorsal suture.

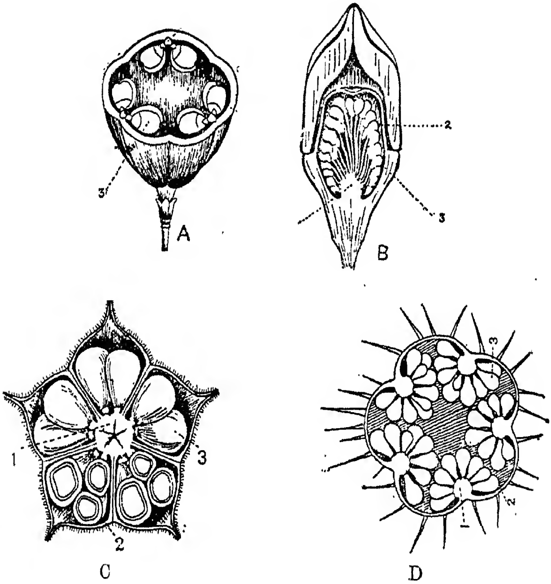


FIG. 261. Different kinds of placentation. A, D, parietal; C, axile; B, basal. 1, placentum; 2, wall of the capsule; 3, seeds.

In many plants the styles are quite distinct and they may be long or short, but there are also flowers in which it is very short or absent. The style in many cases becomes divided into branches at the free end, the branches corresponding in number with the carpels. The stigma is situated at the free end of the style, or on the top of the ovary. It may be simple or it may become branched, sometimes very much so as in the ovaries of grasses. We shall have to speak about this part later on in connexion with pollination.

We have already learnt that the flower stalk bears the parts of the flower at its free end; and this end which is

termed the **receptacle** (also **torus** or **thalamus** by some authors) is subjected to some modification. It is in some flowers somewhat swollen, as in Argemone and Tribulus. In this case all the parts of the flower arise from the top of it, the ovary being superior, and the other parts below it **(hypogynous)**. As already pointed out, the ovary is inferior in Coccinea and Crinum, but the other parts are superior **(epigynous)**; and this is due to the modification of the receptacle. This structure instead of remaining

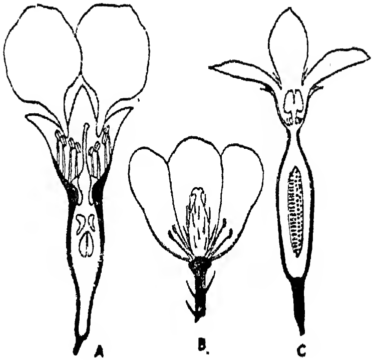


FIG. 262. The receptacle and its modifications. A, receptacle fused with the ovary, only at the base; B, receptacle separate and prominent; C, receptacle completely fused with the ovary.

convex becomes hollow, and encloses the ovary. The wall of the ovary becomes fused with the receptacle. Sometimes the receptacle becomes hollow, but remains open at the top, as in the flower of pomegranate. The calyx, corolla and the stamens spring from the prolonged edge of the thalamus **(perigynous)**.

CHAPTER XVII

THE ESSENTIAL ORGANS AND THEIR FUNCTIONS

THE main function of the flower is the production of seeds, and for the setting of the seeds two distinct processes are necessary. They are the transference of the pollen-grains from the anthers to the stigma **(pollination)**, and a fusion of a bit of the protoplasm of the pollen-grain with a portion of the protoplasm within the ovule **(fertilization)**. We know that the parts of the flower directly concerned in these processes are its essential organs, the stamens and the pistil.

For the clear understanding of these two processes, a knowledge of the essential organs is necessary. The stamens are the parts intended to produce the pollen-grains. A stamen usually consists of a filament and an anther, but it is the anther alone that is of importance. The filament is only a stalk supporting the anther, and we have many instances in which the filaments are absent, the stamens being reduced to mere anthers. To study the structural details, the stamens of Tribulus may be used, as it is typical of the anthers of a good number of plants. A transverse section of this anther reveals two distinct lobes with two cavities in each, filled with pollen. But the lobes of an old anther present only a single cavity, as the two cavities get fused. The anther lobes are held together by the connective, which is traversed by a vascular bundle. The wall of the anther consists of two layers of cells, an outer layer or the epidermis and an inner layer in which the cells have special thickenings (and hence called fibrous cells). This differentiation in the cells of the wall of the anther is intended to facilitate its dehiscence. The outer wall of the cells of the epidermis bulges slightly outwards and there is protoplasm within these cells. Until the maturity of the anther these cells remain in a turgid condition. The pollen grains take some time to develop and until they are fully formed they

need protection. So the wall of the anther remains intact and does not burst, till the pollen is ripe enough for shedding. As long as the epidermal cells are turgid they exert pressure on the fibrous cells lying below the epidermis. As the anther approaches maturity the epidermal cells begin to lose water gradually. This means the gradual lessening of the pressure on the fibrous cells and, as soon as they are freed from it, they tend to expand and assume their natural size. The removal of compression on the fibrous cells leads to the curling of the anther wall. This, of course, causes the wall to break in some place where it is weak.

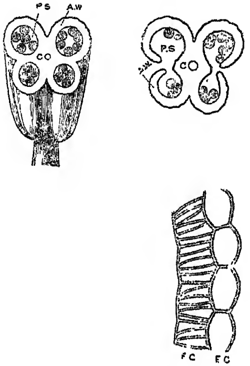


FIG. 263. Structural details of the anther of *Tribulus terrestris*. C, connective; A.W, anther wall; P.S., pollen sac. The third figure is the anther wall highly magnified, F.c, fibrous cells; E.c, epidermal cell.

The pollen-grain of *Tribulus terrestris* is round and it is only a bit of protoplasm enclosed by a cell wall in which two distinct layers, an outer cutinised and an inner cellulose layer, can be distinguished. The outer layer is thickened in a peculiar manner as shown in fig. 264. The inner layer is smooth and uniformly thick. There is a great deal of variation in size and form, and the sculpturing of the outer layer in the case of the pollen-grains, according to the species of the plant. Those of very showy flowers are in many cases provided with spiny or other kinds of projections, or the outer layer may be sticky. In a few cases, we find some spots in the wall formed beforehand for the coming out of the pollen-tube.

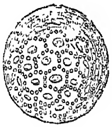


FIG. 264. Pollen-grain of Tribulus very highly magnified.

Some pollen-grains have special lids also, as in the case of Cucurbita.

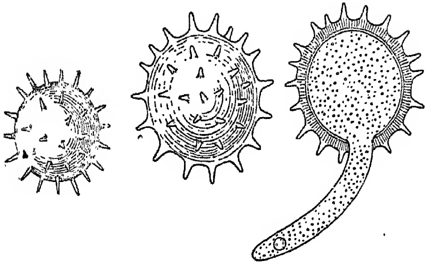


Fig. 265. Pollen-grains of Hibiscus and Thespesia (highly magnified). Note the germination of the grain.

The free end of the style or the stigma is the part intended for the reception of the pollen. It has to catch the pollen-grains and retain them, and also to assist them to germinate. The surface of the stigma is usually rough due either to papillæ or hairs, and a sticky juice containing some sugar is also secreted by it. Both these conditions are useful in retaining the pollen-grains on the stigma.

Sometimes the stigma becomes very much branched and is consequently plumose, as in the case of grasses. It is said that the pollen-grains are safeguarded from the attacks of

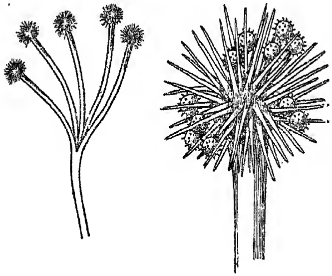


Fig. 266. Germinating pollen-grains of sugarcane.

Fig. 267. Stigma of Hibiscus. The first figure shows the five stylar branches bearing the stigmas (slightly magnified) and the second figure is a stigma with pollen-grains (highly magnified).

bacteria, by the stigmas secreting some substance detrimental to their growth. A stigma is not always receptive ; it becomes receptive as soon as the flower opens and generally continues to be so for sometime, this period varying with the kind of the plant. The sugary juice secreted by the stigma seems to be necessary to stimulate the pollen-grains to germinate. It is only when the stigma is receptive that we find the sugary juice, and if it is absent it is an indication that the stigma is not receptive.

The ovule which develops into seed after fertilization lies within the ovary. It does not develop into a seed unless a bit of protoplasm from the pollen-grain finds its way into the

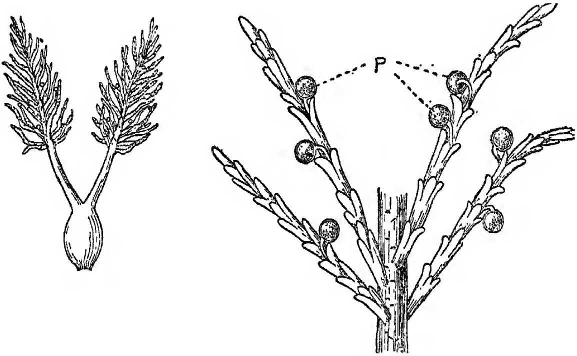


FIG. 268. Stigma of a grass plant. The first figure shows the whole of the pistil and the second shows fine branches of the stigma with pollen-grains germinating, as seen under high power. P, pollen-grains.

interior of the ovule and mixes with a definite part of the ovule. When the ovule is fully formed and ready to receive the bit of protoplasm from the end of the pollen tube, it consists of a large cell, called the **embryo-sac**, amidst a mass of cells (the nucellus). This mass is covered, except at the top, by two membranes called the **integuments**. The opening at the top is called the **micropyle**. The embryo-sac at this stage possesses two groups of nuclei one at the top and the other at the bottom. In each of these groups, there are three nuclei

Of the three lying at the top of the sac close to the micropyle, one nucleus is slightly larger than the others, and this is called the **egg-cell.** The other two cells, called **synergids,** seem to be helpful in directing the contents of the pollen-tube to the embryo-sac. The three cells at the other or far end of the embryo-sac, called **antipodal cells,** do not seem to take any part in the formation of seed. Within the embryo-sac midway between the two groups of nuclei, lies a single large nucleus, which is called the nucleus of the embryo-sac, or the **secondary nucleus.** (See Fig. 271.)

The pollen-grain, deposited on the stigma, emits a tube and this comes to the top of the embryo-sac finding its way through the style and the micropyle. At the end of the pollen-tube we find two nuclei, and both of them get into the interior of the embryo-sac and one fuses with the egg-cell and the other with the secondary nucleus. This fusion of the nuclei of the pollen-grain with those of the ovule is really the process of fertilization. It is only after this fusion that the egg-cell is capable of division and development into the young embryo plant that we find in the seed. The secondary nucleus divides and gives rise to the endosperm, after the fusion of the nuclei.

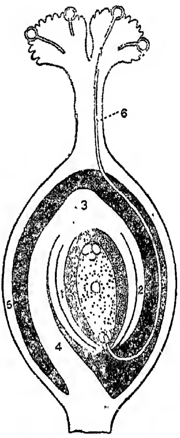


Fig. 269. A diagram to illustrate pollination and fertilization. 1, inner integument; 2, outer integument; 3, chalaza or base of the ovule; 4, funicle; 5, wall of the ovary; 6, pollen-tube. The ellipsoidal white space within the integuments is the embryo-sac

Now it is obvious, that, for the production of offspring, the fusion of the male and female cells is essential even in the case of plants, as it is in the case of animals. Further, the offspring is likely to be better in quality when the sex cells uniting together are from different plants.

The pollen-grains of a good many of the flowering plants have no power of spontaneous movement. So they have to

depend upon some external agency for the pollination of their flowers. Even in the case of plants with bisexual flowers, extraneous aid is necessary for pollination. The transfer of

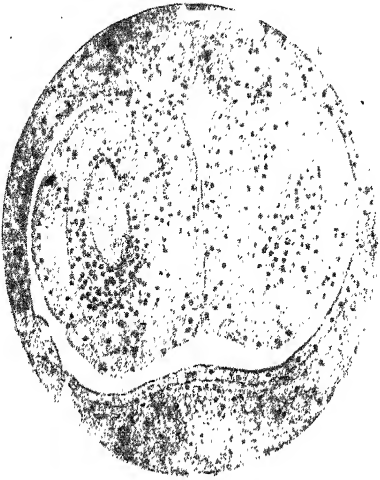


Fig. 270. A photomicrograph of a longitudinal section of two ovules of a lily under high power showing the secondary nucleus. (From a slide prepared by Dr. M. A. Sampathkumaran)

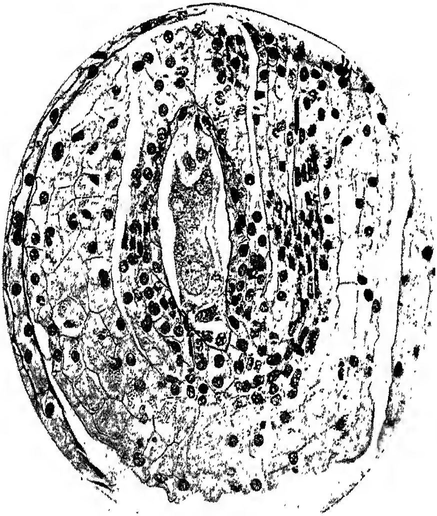
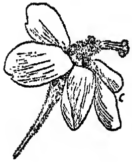


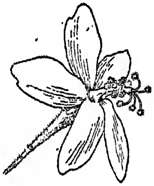
Fig. 271. A photomicrograph of a longitudinal section of an ovule of a lily under high power showing the egg-cell, the synergids and the antipodal cells. (From a slide prepared by Dr. M. A. Sampathkumaran.)

pollen to the stigma from the anthers of the same flower, as well as from the anthers of a different flower on the same plant, is called **self-pollination.** Pollination of the stigma of a flower with the pollen from flowers of a different plant is called **cross-pollination.**

As a matter of fact, self-pollination occurs in several plants especially annuals. In some cases flowers are self-pollinated regularly and such flowers are usually small and inconspicuous without smell or honey. As examples for this, we may mention the Chenopodiums. We have also certain plants wherein self-pollination is made impossible in the earlier stages, but later, just before fading, this becomes possible. For instance, in the flowers of *Hibiscus micranthus* and *Abutilon indicum* the style branches project a little above the anthers just when the flowers open, and so the pollen cannot reach the stigma. It is evident that pollen from a



A



B

FIG. 272. Flower of *Hibiscus micranthus*.
A, morning and B, evening positions.

different flower has to be brought and deposited on the stigmas by some agency, either wind or insects. If the stigmas fail to receive foreign pollen, they bend down so as to come near the anthers in the same flower, to be at least self-pollinated. In both these flowers, the petals close and press on the style branches and thus assist them in coming near the anthers. In some flowers, as in *Evolvulus alisinoides*, the style lies bent away from the anthers just, at first, but later it changes its position, so as to bring the stigma nearer the anthers to make self-pollination possible.

The flowers of *Mirabilis jalapa* are also adapted for self-pollination, when cross-pollination fails to occur. These flowers open towards the evening and emit a very strong scent. Just then, both the stamens and the stigma are far exerted, the stigma alone projecting above the stamens.

Usually two species of moths visit these flowers and if they are not visited by any insect, the stigma manages to get self-pollinated either by the elongation of the stamens or by the slight bending of the style, so as to reach the anthers.

The flowers of some Compositæ are specially interesting in that they have special adaptations in their floral mechanism to secure self-pollination, should cross-pollination fail to take place. For example, in the plant *Tridax procumbens*, a weed found everywhere, the heads have bisexual flowers in the central portion of the disc and the ray flowers are all female. The stamens are epipetalous and the anthers are adherent, so as to form a tube. The style is bifid and the branches are pressed together, in such a manner that the receptive surfaces are in contact and so not exposed. At first, when the flowers are unopened, the style is short, but, as soon as the flowers begin to open the anthers dehisce and the style elongates. So the pollen, lying in the anther tube, gets pushed out and remains at the top of the anther tube. The tip of the style may also carry a small amount of pollen, besides what may adhere to the hairs of the style branches on the outer surface. The style grows and after projecting a little above the anther tube, the branches separate and diverge, exposing the receptive surface. The stigmas thus exposed remain receptive for some time so that cross-pollination may occur. If the stigmas fail to receive pollen by insect visits the style branches diverge still more and even curl round, so that the receptive surface may come in contact with the pollen adhering to the lower surface of the style branches, or with the pollen lying at the top of the anther tube. Self-pollination is thus ensured, if cross-pollination has not already taken place.

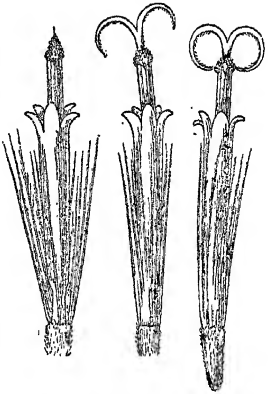


FIG. 273. Floral mechanism of the flowers of *Tridax procumbens*.

Instead of this makeshift arrangement to secure self-pollination, when cross-pollination is a matter of some difficulty, some plants produce two distinct sets of flowers, one adapted for cross-pollination and the other for self-pollination. In *Commelina benghalensis* we have a plant of this sort. The beautiful blue flowers are regularly cross-fertilized and the underground or low-lying inconspicuous flowers that remain as buds without opening are self-fertilized. These inconspicuous flowers are called **cleistogamous** flowers.

Charles Darwin, the great English naturalist, proved by a series of experiments with different plants that cross-pollination is more advantageous to a plant than self-pollination. If we examine flowers of a number of wild plants growing in a place, we find in them numerous contrivances favouring cross-pollination to the exclusion of self-pollination. Recent workers in the field of plant-breeding have also established beyond doubt, that cross-pollination is not only more advantageous to the plant than self-pollination, but it also confers on plants certain racial advantages.

A most perfect arrangement to ensure cross-pollination is to have the essential organs on separate flowers. We find a host of plants in which the flowers are unisexual. In some plants, as in Cucurbita and Ricinus, we find both male and female flowers on the same plant (**monœcious**), in others, as in *Coccinea indica* and in some palms, the male and female flowers are found on different plants and not on the same individual (**diœcious**).

Bisexual flowers become adapted for cross-pollination to the exclusion of self-pollination, by having the essential organs active at different times. The stigmas may mature and become receptive prior to the anthers. In Cumbu (*Pennisetum typhoideum*) spikes, the stigmas protrude from the spikelets and become receptive, while the anthers are still within the glumes. Such flowers are called **protogynous**. The female sexual organs in the protogynous flowers are ready for fertilization long before the anthers are ripe in the same flower, and, therefore, the flowers have to be pollinated only by the pollen of older flowers. There are also plants wherein the stamens shed their pollen prior to the receptivity of

the stigmas. The flowers are then termed **protandrous.** Protandry seems to be more common than protogyny. Flowers of several Compositæ, and Malvaceæ are protandrous. Pollination in this case is effected by the pollen from younger flowers.

In very many plants self-pollen is sterile, as in the case of many leguminous plants. The pollen in the flowers of certain orchids is said to act as a poison, if it falls on the stigma of the same flower. There are also instances in which the pollen from the same flower fails to fertilize, if foreign pollen falls on the stigma, soon after self-pollination. This means that foreign pollen is prepotent over self-pollen.

Another very effective arrangement promoting cross-pollination exists in the flowers of several species of Jasminum. The corolla in all cases is tubular and the stamens are epipetalous. In some flowers the style is short reaching only half the length of the tube, whereas the anthers are at or near the throat of the corolla. On the same plant we also find flowers in which the styles are longer and coming up to the throat of the corolla, while the stamens remain within the tube about midway.

In the case of land plants it is obvious that for cross-pollination some extraneous aid is necessary, because of the fixity in position of these plants and of the absence of spontaneous movement on the part of the pollen-grains The agents usually active in this work are wind and insects and, in rare cases, water. Plants depending upon insects for fertilization are very many, and those pollinated by wind are not inconsiderable.

When plants depend upon wind for pollination, the stigmas have to wait for the pollen that may be wafted by the wind, and this is purely a matter of chance. Therefore, we should expect to find certain conditions specially favourabl to this process in these plants. In the first place, large quantities of pollen should be available to ensure pollination Winds may carry large quantities of pollen, but the pollen likely to fall on the stigmas can only be proportionately very inconsiderable. And, therefore, the flowers that are to b wind-pollinated should stand out far above the foliage leaves so that the pollen may not be hindered from reachin the flowers. This is exactly what we find in the case o

wind-fertilized plants. For instance, in grasses, which are wind-pollinated the inflorescence rises far above the level of the foliage; in the case of trees dependent on wind for pollination, flowers appear, in most cases, at a time when the leaves have all fallen. As an example we may mention the tree, *Odina Wodier*.

The abundance of pollen is secured either by increase in the number of stamens in bisexual flowers, or by having a large number of male flowers. Sometimes the anthers become larger and produce plenty of pollen. To give a vivid idea of the abundance of pollen produced by this class of plants, we may mention the male spikes of Pandanus. A single plant is capable of producing a very large quantity of pollen. It has been computed by some American botanists that a moderate sized *Zea Mays* plant produces about 50,000,000 pollen grains. The pollen produced by these plants should also be adapted for being carried by the wind. So these grains are smooth, light and dry. The anthers are in most cases versatile, an arrangement best suited for the shaking out of the pollen very readily.

The stigmas also have certain adaptations so as to enable them to catch the stray pollen floating in the air. They are branched and plumose, thus getting a large amount of surface. All grasses and sedges, some Amaranths, Ricinus, Pandanus and Odina are wind-pollinated.

From this we see that wind-pollination involves the expenditure of a large amount of energy. As the pollen-grains are composed almost wholly of protoplasm, a material most difficult to manufacture, this enormous production of pollen-grains cannot but be a drain on the resources of the plant. But this is necessary for ensuring pollination.

We have now to consider plants that are pollinated by insects. For successful cross-pollination flowers should be visited regularly and systematically by insects. Casual and erratic visits, or indiscriminateness in the choice of flowers for visits are not likely to be beneficial. Insects should have some inducement to visit the flowers. Flowers, as we know, produce pollen and honey, and both these substances are sufficient inducements to attract the insects and also ensure their visits. By the mere secretion of honey in the flowers

the insects cannot be allured. To ensure their visits, it is absolutely necessary that the place where honey is secreted should be made known to them. The colours of flowers are meant to show them the place where honey may be obtained.

The infinite variety in colour and form of the flowers, as well as the different scents, are intended to attract the insect. In many plants the petals or the corollas are large and coloured so as to be very conspicuous. If the flowers are small, they are rendered conspicuous by being massed together. Sometimes instead of the petals, bracts play the same part, as in Bougainvillæa. Stamens also partake in this work, in Neptunia and Dichrostachys. There are also instances of flowers wherein the calyx becomes highly coloured, while the corolla is absent. The brightly coloured part in the flowers of Mirabilis and Boerhaavia is the calyx. Even when the petals are present the sepals become coloured like the petals, and we have such examples in Cassia and Cæsalpinia.

The colour and the scent of the flowers are no doubt quite sufficient to attract the attention of the insects, but to ensure the regular visitation of insects this is not enough. Something more substantial should be offered to them to induce them to frequent the flowers very regularly. The pollen serves as food, or as material for building the hives for some insects such as the bees. Further, nectar or honey is also secreted in several flowers. Insects such as moths and butterflies live mostly on nectar. As both these substances, honey and pollen, serve as food for these insects, they come to the flowers.

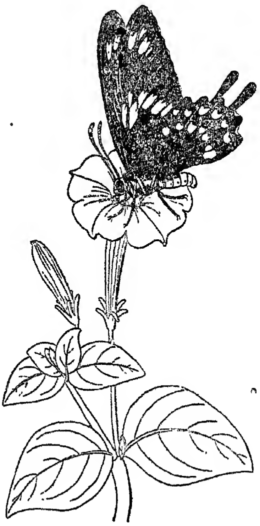


FIG. 274. Butterfly sucking honey from the flower of Petunia.

Insects that visit the flowers are bees, butterflies,

moths and flies. All these insects have sucking apparatus, which in the case of flies are short and in moths and butterflies they are very long and coiled like a spring. Bees take in honey and also gather pollen: moths, butterflies and flies drink only honey. As stated above, these insects visit the flowers, because they get food in the form of honey or pollen. Therefore, the secretion of nectar or honey is essential to ensure their visit.

In the case of insect-pollinated flowers, pollen need not be abundant. So, in these flowers, stamens are generally fewer in number. Further, the grains have usually a rough surface which often also becomes sticky. Stigmas need not have a large amount of surface as in the case of wind-pollinated flowers. The special adaptations in these flowers are so perfect that pollination is a certainty.

The nectar or honey is secreted usually by a disc at the base of the ovary. There are also instances of petals and sepals having nectaries either as glands, or as special pouches, sacs or spurs. The position of the nectary and the arrangement of the other parts of the flower are such as to make it impossible for the insects to get at the honey, without at the same time effecting pollination. It must also be remembered that, if the visit of the insect is to be of use in pollination, it is absolutely necessary that the part of the body of the insect which comes in contact with the anthers should also come in contact with the stigma; otherwise pollination will not take place.

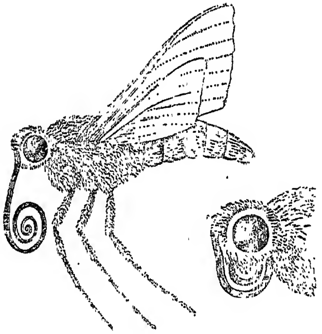


FIG. 275. Head of Moth showing the length of the proboscis.

In flowers in which the corolla is regular and shallow any insect can get at the honey and effect pollination. For instance, in the Tribulus flower there are honey glands at the

base of the stamens and between the petals; the corolla is shallow and the stamens stand erect and so any insect, a bee, or butterfly or a fly can get at the honey. In trying to get at the honey the lower portion, or the sides of the insect must necessarily get dusted with the pollen, and as the stigma is also of the same height as the stamens it must also touch the same part of the body of the insect.

Flowers having long tubular corollas like those of Vinca and Jasminum, or papilionaceous corollas like those of Phaseolus, Indigofera and Vigna are not meant to be visited by all kinds of insects. Only butterflies and bees are able to get at the honey, and in their manœuvres in search of honey they cannot help pollinating the flowers. Other insects cannot get at the honey, and so they do not visit these flowers.

Colour of the petals, though intended to show off well by contrast, is probably not capable of attracting insects as well, as the scent of flowers and the smell of honey. The Mirabilis flower affords an example in support of this statement. This flower is visited by one or two species of the hawk moths; and there are several varieties of Mirabilis and in all of them the flowers open towards the evening and emit a strong scent. Some time after sunset the flowers that are white, light-yellow or cream-coloured alone can be seen and the magenta-coloured flowers cannot be seen. Yet the moth visits both the white and red flowers with equal ease. Insects cannot see the colour from a distance, their range of vision in this respect being limited to within a few feet. Again they are able to see some colours better than others. Bees are said to perceive blues better than yellow. Scarlet does not seem to attract them. Many of the insects visiting the flowers are usually busy with only one kind of flower at a time. For instance, the common Carpenter bee was seen while sucking honey from *Bauhinia tomentosa* flowers. For over quarter of an hour it continued to hover about the same flowers, although there were several other flowers close by, that are usually visited by these bees. On another occasion this bee was thus visiting only the flowers of *Dolichos Lablab.*

Having considered the question of pollination in a general way, we shall now deal with a few flowers in a more detailed manner. The flowers of Papilionaceæ are specially adapted

for cross-fertilization. At the base of the ovary there is usually a disc, which secretes plenty of honey. As the stamens are united by their filaments the honey finds its way into the staminal tube. Of the five petals, the standard is the chief attractive portion. It stands erect and is very conspicuous; in some cases besides being conspicuous it also bears some special marks which are supposed to serve as guides to the place where honey is secreted. The wing-petals invariably constitute a platform for the insects to alight and move about. The insect always sits on the wing-petals with its head directed towards the standard, whether there are special marks or not in it to direct the insect to the honey. Getting at the honey in these flowers is not at all an easy affair. It lies hidden at the base of the ovary and in the trough or cavity formed by the filaments. So it is only very intelligent insects that are likely to get at the honey.

When an insect settles on the flower and moves about, either the stamens or the stigma come out and touch the body of the insect. In some cases, as in *Crotalaria verrucosa* and *Tephrosia maxima*, when insects alight on the wing-petals and move about, pollen-dust is ejected from the pointed tips of the keel-petals first and then the stigmas come out when the insects visit the flower later.

In the flowers of *Vigna Catiang* the filaments of nine stamens are united, one stamen alone being free. At the base of the ovary and around it there is a disc secreting honey. The petals are all connected at the base by means of outgrowths, dents and foldings in such a manner that the standard stands erect, the wing-petals spread themselves out horizontally so as to serve as a platform and the keel-petal remains below. The margins of the keel-petals are united, both above and below, except at the free end where there is a small opening just enough for the emergence of the stigma. When the wing-petals are pressed down, the keel gets depressed and the stigma pops out, and when the pressure is removed, it resumes its original position. In this flower the anthers shed their pollen, before the stigma becomes receptive. Although the stigma is close to the anthers, the pollen does not reach it, because of the hairs found on the style a little below it. Even if a few grains fall on it they will not

germinate, as the stigma is not receptive. When a bee or butterfly alights on the wing-petals the stigma comes out and brushes against the lower part of the body of the insect. If there is pollen already on the body of the insect the stigma gets pollinated. If on the other hand the visit is at a time when the anthers are dehiscing, the lower part of the body of the insect will be dusted with the pollen, and the same part of the body is sure to come in contact with the stigma when it goes to another flower.

In the plant *Indigofera enneaphylla* the floral mechanism is of a peculiar sort. In the flower the keel-petals have short spurs at their sides and they are intended to support the wing petals and keep them in a horizontal position. A very slight pressure on the wing-petals is enough to depress the keel-petals and separate their upper margins. As soon as the keels get depressed, the stamens and the style seem to come up with a jerk and remain outside. The essential organs cannot regain their original position, because the petals fall off as soon as the flower has received a single visit. So in this case one single visit of the insect is enough for cross pollination. Instances of the same kind of explosive arrangement are afforded by the flowers of *Abrus precatorius* and *Alysicarpus rugosus*.

The flowers of Phaseolus are very interesting in their structure and behaviour. Like other papilionaceous flowers these also depend on insects for pollination ; at any rate the arrangement of the petals and the position of the essential organs are such that self-pollination cannot take place. The keel-petals are in this flower prolonged into a beak and the beak is in the form of a spiral. The end of the spiral in the flower of *Phaseolus trilobus* and *P. Mungo* is towards the right, looked at from the front. The right keel-petal possesses a spur which supports the right wing-petal and helps it in retaining a horizontal position, so that it may serve as a platform for insects visiting this flower. There is a distinct passage between the right wing

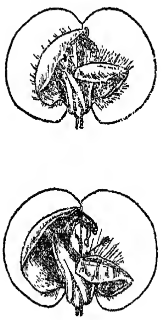


Fig. 276. The floral mechanism of *Phaseolus trilobus*.

petal and the end of the keel-spiral, leading to the base of the standard where the honey is found. The left wing-petal lies higher than the right over the keel on the left side. An insect can get the honey only from the right side. On the left side the wing-petal, the keel and the standard are all close together and there is no opening. An insect coming to this flower for the sake of honey will, of course, alight on the lower wing-petal on the right hand side. As soon as it alights on the wing and begins to search for honey there will be some pressure exerted on the wing-petal. The keel will also be depressed on account of the spur which supports the wing-petal. Then the stigma will come out through the opening at the end of the keel-spiral which lies just above the wing-petal which rests on the spur of the keel on the right side. Inasmuch as the insect is on the platform, the stigma touches the back part of its body. If the stigma is receptive and if the back of the insect's body is already dusted with pollen, pollination takes place. If on the other hand the insect visits a flower for the first time to start with, it will get dusted with the pollen, and the next flower visited will have its stigma pollinated.

In *Leucas aspera* and *L. linifolia* the corolla is bilabiate and the stamens are epipetalous and didynamous. The stamens and the style are enclosed within the upper lip of the corolla. Honey is secreted at the base of the ovary and when the insect alights on the lower lip of the corolla to suck the honey, the stamens and the stigma are released from the upper hood of the corolla. As both the anthers and the stigma are turned downwards they will touch the back of the insect; if the insect is already dusted with the pollen then the stigma will be pollinated, and in case the visit is for the first time the back of the insect gets dusted with pollen.

The flowers of Acanthaceæ have also special devices for pollination. In many plants of this family the stamens lie within the corolla in such a way that they cannot help coming in contact with the back of the insect when it sucks honey. Even small inconspicuous flowers are regularly visited by butterflies. On one occasion in the month of October while engaged in collecting plants, the tiny flowers of *Justicia procumbens* were constantly visited by the small

pretty violet butterfly, Zizera lysimon. At first the flowers of *Justicia procumbens* were not noticed; this small butterfly was seen hovering about and settling on this plant. On close inspection it was found to suck honey from the tiny flowers of the Justicia. These plants were not at all numerous and there were stray plants, scattered all over the place. The violet butterfly continued to visit these flowers persistently for over twenty minutes. The insect proved a most satisfactory guide to lead to the places where this species of Justicia was growing. Similarly another butterfly, a white one with a red border on the front wings, was seen visiting the flowers of *Spermacoce hispida* with great assiduity. The flowers of *Tephrosia purpurea* were visited by a butterfly with golden yellow wings. The flowers of Tridax were watched to see what insects visit them for honey and pollen. Seven different species of insects were found visiting these flowers and they were Zizera lysimon, Coletis amata, Catopsilia pyranthe, Terias hecabe, Parnara mathias and Ceratina viridissima.

There are flowers that are exclusively pollinated by the visits of flies. The flowers of Aristolochia and Aroideæ are of this kind. A very fœtid odour is usually emitted by some of the Aristolochias and in one species the smell is so strong as to attract flies from very long distances (fifty to hundred yards or more). In this flower the anthers are situated on the style below the stigma and they dehisce, after the withering of the stigma. Inside the tubular perianth, when it opens there are found a number of hairs all directed inwards. (See fig. 244.) The flies get into the perianth tube easily. But they cannot get out of it with the same ease, on account of the hairs. This flower is protogynous and therefore it has to be pollinated by pollen from some other flower older than itself. When the flies get inside the flower they pollinate the stigma if they have already visited other flowers; if on the other hand the visit of the insect is its first visit, it gets dusted with the pollen. When the flies get into the flower, the anthers are usually immature and the flies cannot get out of the flower, until the anthers dehisce, because the hairs dry only then. Until that time the flies will be wandering all over inside, in search of a way to escape; and in their wanderings they

get dusted with pollen. By the time the pollen is liberated the hairs disappear and the stigmas fade, and the way becomes clear for the flies to escape.

The inflorescence of Aroids are particularly interesting on account of the arrangements existing in it for pollination. The spadix bears the unisexual flowers at its lower portion only, those at the very base being female and those above male. (See fig. 225.) Above or between these are a number of reduced flowers in the form of hairs directed downwards. The whole inflorescence is covered by a large spathe, the lower part of which forms a tube constricted a little above the region of anthers, or the hairs, whilst the upper portion is

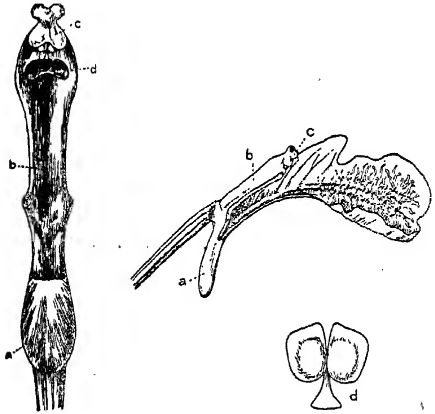


FIG. 277. The essential organs of the flower of *Eulophia virens.* *a*, sac; *b*, style; *c*, anther; *d*, pollinia (shown separately); *d*, stigma.

expanded exposing the upper free end of the spadix. Small flies attracted by the bad smell emitted by the flowers and also by the spathe, crawl down into the tubular part of the spathe. Once they are in, they cannot easily get out from the tubular part, because the neutral flowers are all directed downwards and the spathe is constricted just above these flowers, or the anthers. The flowers are protogynous as in the case of Aristolochia, and so the insect pollinates the stigma if it bears pollen from another plant. If the flower happens to be the first one that is visited by the insect, the insect is

forced to stay within the spathe until the way is open for it to escape. The withering of the downward directed hairs and the dehiscence of the anthers take place together and, therefore, the flies escape with a coating of pollen. They cannot avoid this as the anthers are at the top of the inflorescence, just at the level of the constriction or a little below it.

In the flowers of orchids we have a most perfect mechanism for securing cross-pollination although it is very complicated. As examples we shall select two species of orchids commonly met with in the plains. The orchid *Eulophia virens* grows amidst scrubs and its flowers are greenish with red streaks. There are three sepals and three petals ; the sepals are all alike, but one of the petals, the one lying on the lower side of the flower when it is open, is modified, and it is called the lip. In this flower the lip is slightly saccate at its back and the free front part is broad and in the flower it stands out as a platform for the insects to sit on. The short shallow sac secretes honey and the flowers are visited by butterflies. The anther is single and it is on the top of a column rising from the top of the ovary. (See fig. 277.) The pollen in this and all orchids is collected in masses called **pollinia**, and in this flower there are two such masses in the anther. Just below the anther there is a disc-like gland to which the two pollen masses are attached by means of strap-shaped stalks. The anther in the open flower lies just above the opening leading into the honey-sac. When the butterfly sucks honey the pollen masses stick on to its head, and so the insect carries away with it the pollen masses. The next flower that is visited by this insect is pollinated by the pollen masses sticking on to its head. The stigma lies just below the anther on the front side of the column. When the insect rushes into the flower to suck honey the pollinia cannot help touching the stigma because the pollinia assume a direction which will coincide more or less, with the position of the stigma.

In Habenaria we have another very common orchid of the plains. The flowers in this orchid are all pure white and the raceme springs from the middle of two or three elliptic leaves lying flat on the ground. They are very conspicuous

by reason of the racemes. Both in the morning just before sunrise and in the evenings the flowers are visited by moths. The lip is prominent below and it is prolonged at the back into a very distinct spur, varying in length from quarter of an inch to one inch. The two lateral petals and the sepal lying above are united so as to form a hood. There is a narrow passage leading into the interior of the flower and the anther is situated on a column just above the passage leading into the spur. The pollinia have long stalks and the basal portions of the stalk protrude a little. When the moth gets in, the two pollinia stick on to the head of the insect and when it flies to another flower the pollinia are rubbed against the stigma lying below the anthers and the masses adhere to the stigma, as its surface is very sticky.

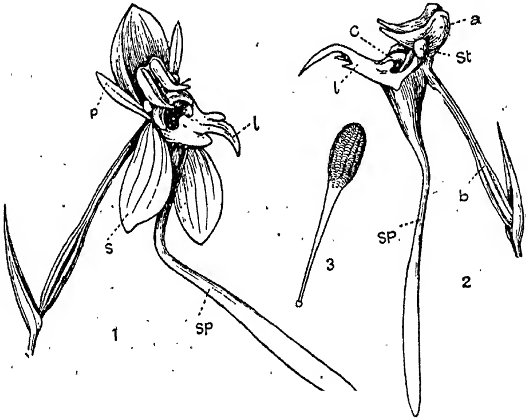


FIG. 278. The floral parts in *Habenaria platyphylla*. *S*, sepal; *P*, petal; *l*, lip or labellum; *SP*, spur; *a*, anther; *b*, ovary; *c*, stigma; *St*, staminode.

In *Calotropis gigantea* (as also in all Asclepiadeæ), the pollen grains are held together in masses and there are ten pollinia. When an insect settles down on the top of the staminal column in the centre of the flower and moves about round the stigma, the pollinia adhere to the legs of the insects. When it flies to another flower the pollinium gets on to the stigma to which it will stick if it is receptive.

There are many plants whose flowers are usually pollinated by moths. As moths move about only during the night or in the dusk, these flowers have white corollas, open in the dusk and also emit a strong scent at this time. The flowers need not be irregular as a platform is not needed, because moths do not alight and they only hover in front of the flower. We may mention as examples Ipomœa, Tobacco, Mirabilis and Jasminum. In these flowers the anthers are generally loose and are well adapted to shed pollen on to the body of a hovering moth. The hawk moths, *Herse Convolvuli* and *Cephonodes picus* visit the flowers of many of the large flowered Ipomœas and the flowers of *Mirabilis jalapa.* The former is a very constant visitor, but the other one comes very rarely and it is extremely active and so rapid in its movements that it is impossible even to see its wings clearly.

We have also plants that depend on water for pollination and they are all aquatic plants. The common water plant, Vallisneria may be selected as a type of plants fertilized by the agency of water. The flowers of this plant are unisexual and the plants are diœcious. Both the staminate and the pistillate flowers develop under water, and so, unless there is some special adaptation, fertilization cannot take place. The male flowers are borne on short stalks almost at the base of the plant. At the time of flowering, or when the flowering season approaches, these get separated from their stalks and rise to the surface of water to float there. Simultaneously, the female flowers lying under water with spirally coiled stalks come up to the surface, in consequence of the uncoiling and growth of the stalk. The male flowers are most numerous and they float amongst the female flowers. The anthers open and the pollen is shed on the stigmas. In the case of flowers that are hermaphrodite, the flowers are raised about the water level, as in Nymphæa, so that they might be pollinated either by insects or by wind. It is only when flowers are unisexual and also submerged, pollination is effected by water currents. In all plants that are pollinated by currents of water the pollen grains are smooth, and pollination also is not a matter of certainty. So in these cases there is an abundance of pollen. During hot weather

when water is low in ponds and tanks we generally see masses of small white flowers floating freely on the surface.

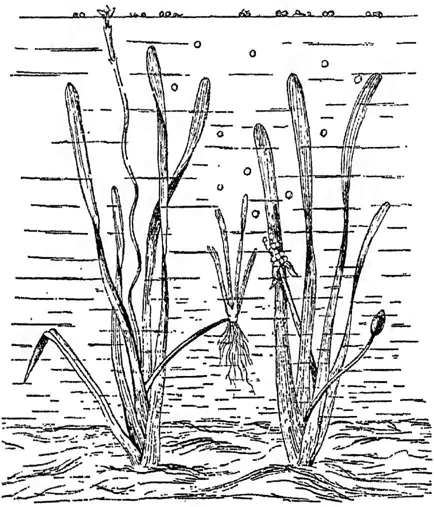


FIG. 279. *Vallisneria spiralis.*

Sometimes the aquatics, which ordinarily raise their flowers above the water, do not do so when rain is heavy. Then the flower buds do not open and are then cleistogamic.

CHAPTER XVIII

FRUIT AND SEED

SOON after fertilization all the parts except the pistil wither and fall off, because they have done their work and are of no further use. But the pistil grows gradually and develops into the fruit. The process of fertilization, besides transforming the ovules into seeds, produces other far-reaching results. The ovules before fertilization remain enclosed in the ovary for protection, and even after fertilization the need for protection is as great as before. Therefore, the wall of the ovary is also stimulated to growth by this process. The seed is dependent upon the placenta and the wall of the ovary for its food supply, and so the pericarp generally grows and becomes fleshy and sometimes even the placenta becomes so.

Although the fruit consists, in most cases, of only the seeds and the wall of the ovary, there are also fruits in which other parts become associated either forming an integral part of it or merely covering it. For instance, the style which almost always dries and falls off not only persists but also grows into a kind of feathery tail in Clematis and into a wing in *Ventilago madraspatana*. (See figs. 316 and 280.) The calyx often grows and envelopes the fruit, as in Physalis and Withania. In the case of some fruits the receptacle becomes hollow with the ovary immersed in it in such a way that these two parts become fused into one; and this is the case in Guava, Pear, Apple and Cucumber. In all these fruits the edible fleshy part consists of both the pericarp and the receptacle. Instances are not wanting of fruits in which even the pedicels are implicated. The edible fleshy

FIG. 280. Winged fruit of Ventilago. The style has developed in this into a wing.

portion in the fruit of Anacardium (Cashew-nut) is only the flower-stalk. (See fig. 284.) Even the floral axis of an inflorescence and the perianth are influenced so as to develop into fleshy structures and form an integral part of the fruit. We observe such changes in the fruits of Artocarpus and the Pine-apple (*Ananas sativus*). All these changes, occurring in parts, other than the pericarp, are not without significance; these changes are highly beneficial to the seeds, because they are helpful in protecting and dispersing them.

From all these considerations it is obvious that it is not an easy matter to define a fruit so as to include all kinds. For the sake of convenience and clearness, however, we define a fruit as a ripened ovary enclosing seeds instead of ovules. A fruit proper consists of only seeds and the pericarp; if other parts are found associated with the fruits we call them **false fruits, accessory fruits** or "**reinforced fruits.**"

A fruit grows, becomes fleshy and may remain so until it leaves the parent plant, as in the case of the fruits of Mango, Guava, Brinjal and Tomatoes. In some cases it gets dry before leaving the plant, as is seen in Abutilon, Tridax and Castor. So it is customary to speak of fruits as fleshy and dry. The division of fruits into dry and fleshy fruits is purely artificial, and it is a matter of convenience. A fleshy fruit, dropping from one species of tree, and a dry one, detaching itself from another species of plant, are not strictly comparable, because they do not represent the same stage of development but belong to two different stages. A dry fruit long before it begins to dry (i.e., when it is fleshy) and a fleshy fruit are comparable, as then both of them are in the same stage.

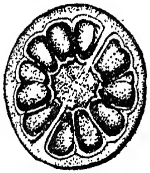


FIG. 281. Berry of Solanum.

The necessity for some kind of classification of fruits arises, because there are so many different forms of fruits. The time-honoured division of fruits into dry and succulent kinds is as good as any other and so we shall deal with them.

Fleshy fruits.—We shall begin with the fleshy or succulent fruits. Examples of fleshy fruits are furnished by such

fruits as the Brinjal, Grapes, Mango, Gourds and the Cucumbers. In all these fruits the pericarp is succulent and, except in the case of Mango, it is so throughout. But in the Mango the inner part of the pericarp is hard and stony. So we have to differentiate the fleshy fruits from one another and group them into distinct classes according to the nature of the fleshy pericarp. Fruits like Grapes or the Brinjal or Tomatoes, with pericarps that are fleshy right through their thickness, are called **berries**. We have in the Plantain, the Pomegranate, and the Guava berries. All these berries contain many seeds and they are fruits that do not open for setting the seeds at liberty. Seeds are allowed to get out by the gradual rotting of the pericarp or the fleshy pericarp may dry and then decay little by little thus setting them free. We have some berries, however, that dehisce, in Melons and Cucumbers ; we have also berries with single seeds and, as an example, we may mention the date fruit.

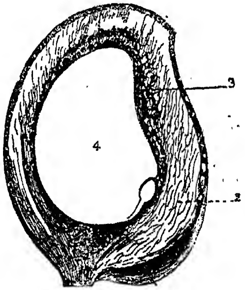


FIG. 282. Drupe of Mangifera. 1, epicarp ; 2, mesocarp ; 3, endocarp ; 4, seed.

There are fleshy fruits in which the pericarp is fleshy only outside, the inner part being hard and stony, as in the case of the Mango fruit. A fruit having this sort of modification in its pericarp is termed a **drupe**. In this type of the fleshy fruit the pericarp consists of three distinct layers; the outer surface skin (**epicarp**), the fleshy middle portion (**mesocarp**) and the innermost hard stony part (**endocarp**). Typical examples of drupes are furnished by the Coconut,

Almond and *Zizyphus*. The mesocarp in the case of the Coconut is fibrous, but in the others it is fleshy; further, there is only one seed in the Coconut and the Almond, which is usually the case in most drupes, whereas in the third there are more seeds than one. There are instances in which the endocarp of a drupe, instead of forming one hard case for all the seeds as in *Zizyphus*, becomes divided into as many separate pieces as there are seeds. This is the case in the fruits of several Verbenaceous plants. Then, to differentiate such fruits from the drupes proper, they are called **pyrenes.**

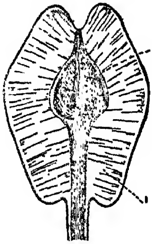


FIG. 283. Pome or fruit of a pear. 1, hollow receptacle; 2, the pericarp.

Even in the case of berries we may speak of special varieties of berries. When the ovary is immersed in the hollow receptacle, the fruit that develops from it is called a **pome.** In these fruits the edible succulent portion is the hollow enlarged receptacle, and the parchment-like core enclosing the seeds is the pericarp. The Gourds and the Pumpkins have a thick epicarp and the placentas are parietal. This kind of fruit is called a **pepo.** Sometimes the pericarp happens to be leathery, as in limes and oranges, the fleshy part being hairs growing from inside the pericarp. These fruits are called **hesperidiums.**

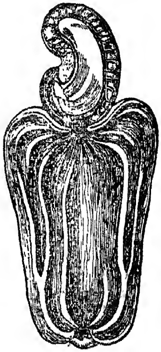


FIG 284. The Cashew-nut fruit.

Dry fruits.—Dry fruits have no food material in their pericarps when they leave the parent plant. These fruits generally open to liberate the seeds, if they contain numerous seeds. Some amongst the many-seeded dry fruits, instead

of bursting open, break into separate pieces, each piece corresponding to a carpel. Most of the single-seeded dry fruits do not open, and the seeds are set free by the decay of the pericarp. So we have both dehiscent and indehiscent dry fruits.

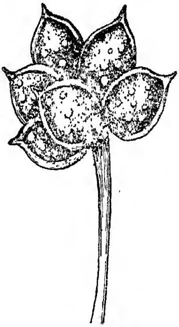


Fig. 285. Achenes of Ranunculus.

The fruits of Compositæ and grasses do not open, and so they are indehiscent dry fruits. In the fruits of Compositæ, the pericarp is thin and dry, and encloses only one loose seed. Such fruits are called **achenes**. Sometimes the individual carpels of an apocarpous ovary develop into single seeded indehiscent bits, as in Ranunculus, Clematis and Naravelia. These also must be called achenes. Sometimes an anchene-like indehiscent fruit possesses a wing, and, then it is called a **samara.** The fruits of *Hardwickia binata*, *Ailanthus excelsa*, *Holoptelea integrifolia*, and *Pterolobium indicum* are samaras. The grains of grasses and cereal plants look like seeds, but they are fruits in which the pericarp and the seed-coats have fused into one membrane and, therefore, the fruits look like seeds. This kind of fruit is called a **caryopsis.**

Fig. 286. Samara of Hardwickia.

There are some fruits with many seeds that divide into as many parts as there are carpels. For example, the fruits of Sida, Pavonia, Leucas, Heliotropium and Castor break into as many pieces as there are carpels. Such fruits are termed **schizocarps.** Each single segment is called a **coccus** and these in most cases contain a single seed. Again, these segments may remain indehiscent, or they may open to let the seeds out.

Next we have to deal with dehiscent fruits. The fruits of Calotropis, Vinca, Dregea, Wrightia and Sterculia consist

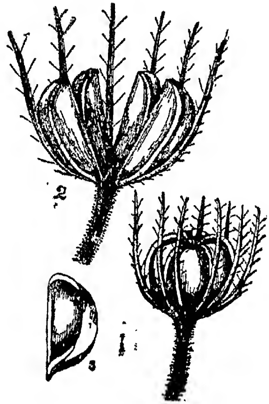


FIG. 287. Schizocarps of *Pavonia zeylanica.* 1, entire fruit; 2, fruit breaking into its component segments; 3, a segment or coccus.

of free carpels, and each of them opens along one margin, the one which bears the seeds (ventral suture). These fruits are called follicles.

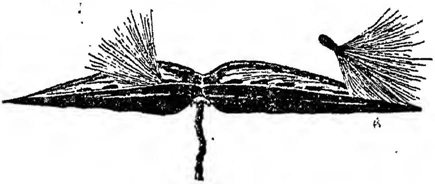


FIG. 288. Follicle of an Asclepiad.

Fruits of Crotalaria, Dolichos, Canavalia, Indigofera and Tephrosia are monocarpellary fruits, dehiscing along both the margins and they are called legumes. In some plants the legumes without opening by the sutures break into separate pieces, each one consisting of a bit of the pericarp enclosing a single seed. Such fruits are seen in some species of Desmodium and Mimosa, and they are termed lomenta.

When a dry fruit is the result of the development of a syncarpous gynæceum consisting of two or more carpels, and

at the same time if it liberates the seeds by dehiscence, it is called a **capsule.** This kind of fruit opens in various ways. For example, those of Ionidium and Impatiens open by means of valves. The dehiscence in this case takes place longitudinally from the top to the bottom of the fruit, the pericarp breaking into distinct valves. This longitudinal dehiscence is sometimes partial, extending only to a small distance at the top of the fruit, as in *Argemone mexicana.* Amongst

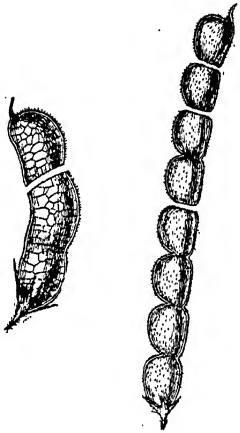


FIG. 289. Legume. FIG. 290. Lomentum.

capsules there is variation as regards the cavities they contain. In Ionidium and Argemone there is but one cavity ; but in the fruits of Hibiscus, Cotton, Corchorus and Aristolochia the locules are more than one. In the case of these fruits also the opening of the pericarp is longitudinal, but the position of the slit varies. Generally the slit appears in the pericarp along the dorsal sutures between the walls of division of the carpels, so as to expose the seeds. This kind of dehiscence is called **loculicidal,** and the fruits of Hibiscus, Cotton and Corchorus are capsules opening in this manner. Occasionally we come across fruits in which the slits appear along the lines of the junction of the carpels, i.e., through the septa or partition walls. In this case the seeds are not

exposed, until another opening takes place. This mode of dehiscence is well seen in the capsules of Aristolochia, and

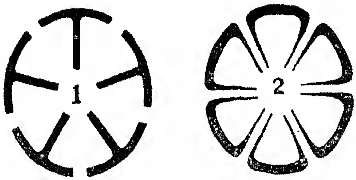


FIG. 291. Loculicidal (1) and Septicidal (2) dehiscence.

the dehiscence is said to be **septicidal**. The separation of the fruit into cocci in the case of schizocarps is the result of septicidal dehiscence. Sometimes, though rare, the pericarp breaks away from the septum just where it joins the partition wall leaving the septa as a column in the centre. This dehiscence is termed **septifragal** and it may be observed in the fruits of Datura. There are also fruits that dehisce transversely, the upper part of the capsule then coming off as a lid. The fruit then goes by the name of **pyxis**. The fruits of Portulaca and Trianthema are of this kind.

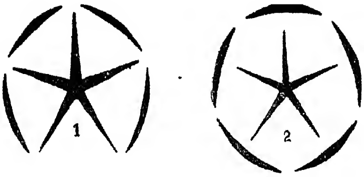


FIG. 292. Septifragal dehiscence. 1, septicidally and 2, loculicidally.

A fruit resulting from the development of a single monocarpellary pistil or from a syncarpous polycarpellary ovary is a simple fruit. If the carpels in a fruit are quite free it is called an **aggregate** fruit.

The fruits of Polyalthia are aggregate fruits consisting of berries. In Clematis, Ranunculus and Naravelia the separate carpels are achenes; and the aggregate fruit of Michelia

consists of free follicles. The Raspberry affords an example of aggregate fruit with **drupelets.**

As already pointed out in the earlier part of this chapter false fruits result from the fleshy development of the whole

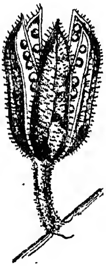


FIG. 293. Capsule of Hibiscus.

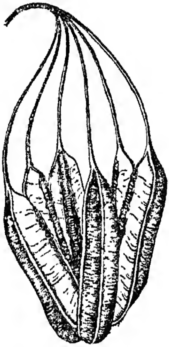


FIG. 294. Capsule of *Aristolochia indica.*

of the inflorescence. The Jack fruit and the Pine-apple are really spike-like inflorescences in which the stalks or axes, as well as the flowers, have become fleshy. The edible "flakes" in the Jack fruit are really flowers consisting of only perianth and the pistil. The succulent fleshy part is the perianth and the membranous bag enclosing the seed is the pericarp. From one side of the pericarp rises the style. These changes in the Pine-apple are still more marked. The polygonal areas seen externally in the case of the Pine-apple correspond to the flowers. The bracts and the withered remains of the other parts of the flower are often visible. But the lower parts of the flowers become fleshy and fuse with the axis.

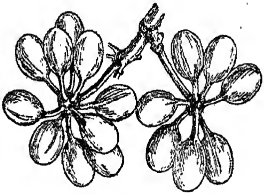


FIG. 295. Aggregate fruit of Polyalthia.

The fruit of the Banyan affords another example of the inflorescence becoming a fruit. The succulent edible portion

of the so-called fig-fruit is the hollow receptacle bearing male, female and gall flowers. The so-called seeds are really so

Fig. 296. Aggregate fruit of *Naravelia zeylanica*.

many achenes. All the species of the genus Ficus bear this kind of fruit and it is called **syccnium** or **fig.**

The Jack fruit, Pine-apple and the Fig are formed from

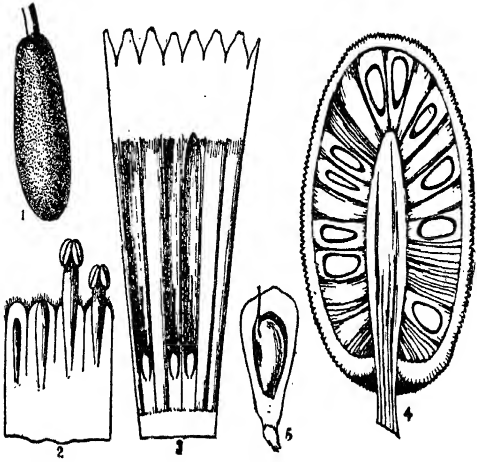


Fig. 297. The Jack fruit and its parts. 1, male spike; 2, male flowers; 3, female flowers; 4, young fruits in spike; 5, young fruit with its fleshy perianth.

an inflorescence and not from a single flower. Therefore these fruits are also called **multiple fruits.**

We have already dealt with the structural details of a few seeds. We know that a seed is after all a young plant wrapped up in the seed-coat and that flowering plants usually reproduce themselves by means of seeds. As the embryo within the seed remains dormant until the time of germination, we may say that the life of a flowering plant is divided into two periods, one short and the other long. The period

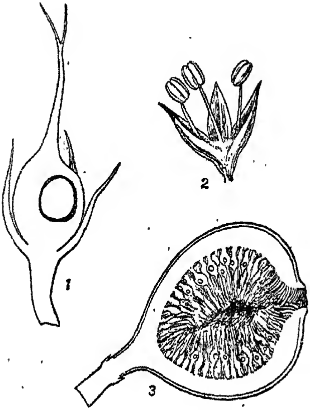


FIG. 298. Syconium or Fig. 1, female flower; 2, male flower; 3, L. sections of a Fig.

of life spent as embryo is relatively short, and until it is allowed to begin the longer course of its life, it needs protection. The seed-coats and the pericarp serve the purpose of protection, and they are also helpful in the matter of dispersal.

Before dealing with the subject of dispersal of fruits and seeds we shall refer to the structure of seeds once more. The essential parts of a seed are the embryo and the enveloping seed-coats; and in most cases we do not find any other part. The embryo itself consists of the primary axis and the cotyledons, which usually contain the food reserve. Such seeds are called non-endospermic seeds. In seeds of

some plants the reserve material remains outside the embryo, but within the embryo-sac. This reserve stuff is called endosperm and, therefore, seeds having endosperm are called endospermic seeds. In the case of the non-endospermic seeds all the food material is absorbed and stored up in the cotyledons as the seed ripens.

In some genera of Leguminosæ even in the fully matured seeds, a small quantity of endosperm is seen to persist, thus forming a link as it were between the endo- and non-endospermic seeds, whereas in the endospermic seeds the reserve material is not transported into the cotyledons, and it is gradually absorbed only during germination. The fact that the reserve material is transferred from the endosperm into the cotyledons becomes obvious if we examine the seeds of several legumes in the course of development. In partially developed seeds of Cassia, Dolichos, Crotalaria, etc., we find the cotyledons embedded in a fleshy mass which is massive in very young seeds and it gradually decreases and the cotyledons increase in proportion. The nucellus of the ovules that are destined to become endospermic or non-endospermic seeds is absorbed gradually and when the embryo is fully formed nothing of the nucellus is left. But there are some plants in which a portion of the nucellus persists and remains as a portion of the seed. For instance, in the seed of the Piper fruit the small embryo is surrounded by a small quantity of endosperm, and the bulk of the seed consists of something lying outside the embryo-sac, though inside the seed-coats. This stuff lying outside the **embryo-sac** is termed **perisperm.** Many plants of the order Piperaceæ and some Nymphæas have seeds with perisperm. In the case of *Elettaria Cardamomum* and Canna also the seeds contain perisperm.

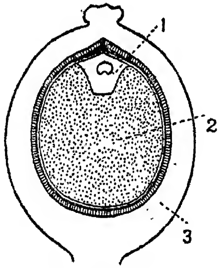
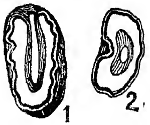


FIG. 299. Piper fruit. 1, endosperm; 2, perisperm; 3, pericarp.

The seed-coats are in most seeds smooth and there is considerable variation in their colour. Besides this we find outgrowths on the testa, either in the form of wings or hairs. In the seeds of Asclepiads and some Apocynes there is a tuft



.300. Cardamom seed. 1, Longitudinal section ; 2, transverse section.
The white portion in the centre is the embryo, the outer black part, endosperm and the outer white portion is the perisperm.

of hairs at one end of the seeds, and in some even at both ends. There are also seeds whose testas are fully covered with hairs, as in Cotton, *Hibiscus micranthus*, *Eriodendron anfractuosum* and *Cochlospermum Gossypium*. Some seeds, such as those of Crinum, have no seed-coats.

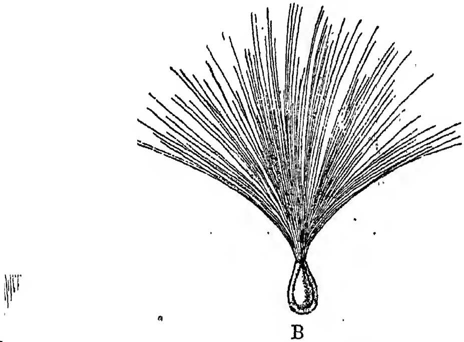


Fig. 301. Comose seeds. A, Alstonia seed; B, Calotropis seed.

Fleshy or membranous outgrowths from the funicle or

the micropyle are found in several seeds, and these outgrowths are called **caruncle, strophiole** or **aril**, according to their origin and size. We have such appendages in Castor, Polygala, Nymphæa, Modecca, *Pithecolobium dulce* and *Myristica fragrans.*

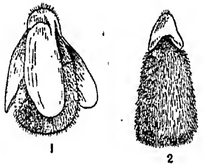


FIG. 302. Strophiole of Polygala seeds. 1, seed of P. chinensis; 2, seed of P. erioptera.

Just like other parts of the seed the embryo also shows variation. Although the cotyledons are equal and similar in most plants, they are not so in all plants. For example, in the seeds of Artocarpus and *Hopea parviflora*, the cotyledons are unequal, one being larger than the other. Further the cotyledons of Hopea are also lobed. Instead of being lobed regularly as in Hopea, it may be very irregularly lobed, as is seen in the cotyledons of Vateria indica. (See figs. 303 and 304.)

The primary axis may remain small and inconspicuous, as in castor seed, and then the plumule and the radicle are not clearly marked out. In *Dolichos Lablab* seeds the axis

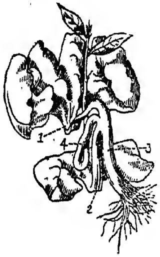


FIG 303. *Vateria indica* seedling showing the inner view of the cotyledons. 1 and 2, lobed cotyledons; 3, hypocotyl; 4, plumule grown into a shoot.

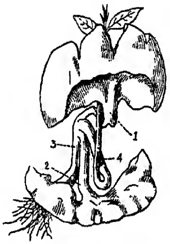


FIG. 304. *Vateria indica* seedling showing the outer view of the cotyledons. 1 and 2, cotyledons; 3, hypocotyl; 4, young shoot.

is well developed, curved and differentiated distinctly into plumule and radicle. When the plumule is distinct the first pair of leaves are also clearly seen on it. The radicle usually projects beyond the cotyledons, especially if it is a well-formed one. The whole of the axis may also remain well within the cotyledons, and even higher up, as in the seeds of Dysoxylon.

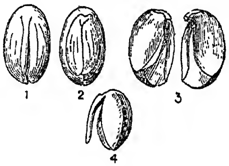


FIG. 305. Parts of the seed of *Hopea parviflora*. 1, Front view of embryo ; 2, back view of the embryo ; 3, 4, cotyledons.

All seeds possessing two cotyledons are called dicotyledonous seeds, and those with a single cotyledon as typified by the caryopsis and the Date seed are monocotyledonous seeds. All monocotyledonous seeds are endospermic. In all endospermic seeds, whether dicotyledonous or monocotyledonous, the embryo is much less developed than it is in non-endospermic seeds.

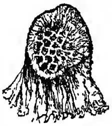
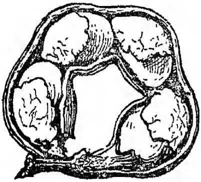


FIG. 306. Aril of the seed of Modecca.

For example, the embryo in the Date seed is a very minute body, found on one side of the stone in a small pit. The stony part is the endosperm.



307. Aril in *Pithecolobium dulce*.

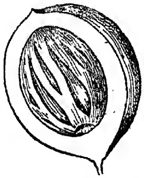


FIG. 308. Aril of Myristica.

There are many plants whose fruits look like seeds, and ordinarily they pass for seeds. The caryopsis of cereals and the achenes of Compositæ pass for seeds. But a close examination of these "seeds" will reveal the fact that they are really fruits and not seeds. Seeds as a general rule never appear nacked and are never exposed at any stage, except by the bursting open of the pericarp. Further, the seeds are always attached by their stalk, and, therefore, there will be only a single mark of detachment or scar. Fruits, on the other hand, have two scars, one, the point at which it was attached to the receptacle, and the other, the style scar.

For the sake of clearness and convenience we may classify the seeds somewhat as follows :—

A.—**Monocotyledonous seeds** (seeds with a single cotyledon).

All monocotyledonous seeds are endospermic and the cotyledon never comes out.

B.—**Dicotyledonous seeds** (seeds with two cotyledons).

(*a*) **Non-endospermic**—the seed consists of the primary axis, the cotyledons and the seed-coats.

(*b*) **Endospermic**—the seed consists of the primary axis with the cotyledons, endosperm and the seed-coats.

(*c*) **Perispermic**—the seed consists of the embryo endosperm and also perisperm. This kind of seed is rather rare.

C.—**Fruits** that look like seeds.

CHAPTER XIX

FRUIT AND SEED DISPERSAL

A FLOWERING plant brings into existence seeds by a considerable expenditure of a material manufactured by it. Mere production of seeds counts for nothing, unless they are given a chance to get themselves established in suitable localities. It is a matter of common observation that most plants produce seeds far more than what can reasonably be expected to germinate and grow. If all the seeds of a plant were to fall below it or even in its proximity, there is sure to be an intense struggle as soon as they all germinate. On account of the overcrowding, a very large number of the seedlings are not likely to get enough food and air, and all but the very strongest would ultimately die. The struggle in this case is very severe, because all the individuals are alike in their mode of growth and all need, more or less, the same kind of food. Even the few sturdy seedlings that survive the struggle cannot be expected to do well, because the soil and other conditions are not likely to be very favourable. If the plants are to grow strong and become sturdy, it is essential that each seed should find a place where it will have plenty of room to grow, besides sufficient air and sunshine. This is possible only if the seeds are scattered far and wide. A seed, in order to have the best chance to grow, must find a place far removed from its fellows. If it is able to do this, its chances of growing to maturity are very great, and the continuance of the species is also thereby ensured.

The distribution of seeds is essential for the proper development of the individual plants as well as for the maintenance of the species. Flowering plants are rooted to the soil and are unable to move. Yet we see plants of the same species growing far and wide and some species are found distributed all over the world. This is undoubtedly due to the wide distribution of the seeds of plants, and for dispersal the seed stage of the plant is best suited; the embryo lies dormant, and its vitality being suspended it can withstand changes in its environment.

As already mentioned, plants are capable of producing seeds in large numbers. In spite of the prolificity of most plants in the matter of seed production, in nature we do not see any one species developing and occupying considerable areas to the exclusion of others, except under very special conditions. Even plants producing a small number of seeds would occupy a very large portion of the earth in a few years, if all the seeds produced in successive generations were to grow successfully into plants after germination. The great naturalist Linnæus made out by calculation that a plant producing only two seeds in a year will number over a million in twenty years, if all the seeds that are produced in every successive generation are capable of growth. This estimate is very low and does not give us an adequate idea of the rapidity with which a species is able to spread. Ordinarily plants produce a very large number of seeds. A Tobacco plant, for instance, produces from 300,000 to 350,000 seeds; *Argemone mexicana* from 20,000 to 25,000 seeds. According to Kerner if a Henbane plant producing on the average 10,000 seeds a year were allowed to grow undisturbed and, if all the seeds produced each year is capable of full development, the whole of the dry land would be occupied at the end of five years. Another plant Sisymbrium which produces 730,000 seeds a year would occupy an area 2,000 times as great as the surface of the dry land in the course of three years.

Considering the risks to which the seedlings are exposed and the deaths taking place in the competitive fight, the overproduction of seeds becomes a sheer necessity. The struggle is so fierce and the dangers to which these are exposed are so formidable that one is justified in wondering how even a few have survived. But, for the maintenance of the reasonable average number both as regards the individuals and the species, the overproduction cannot but be a distinct advantage. Another advantage is that the species is likely to spread to new spots that are favourable. Even if many succumb in the struggle a few at least are likely to fall in situations remote from the parent and such situations are always good for them. It is a well-established fact that occasional driftings to different surroundings act beneficially in stimulating the plants to good growth.

There are other considerations regarding the seed that are also of very great importance in this connexion. The success or failure of a plant to become well established depends, to a certain extent, upon the amount of reserve food material existing in a seed. Some seeds as in the Coconut are large and there is a large quantity of food stuff available for the young plant. So it can make use of it, until it is able to prepare its own food. When seeds are massive the production of seeds is by no means large, numerically. If, on the other hand, the seeds are small the number produced by a plant ought to be very large, because the food carried by the seed for the embryo is very limited.

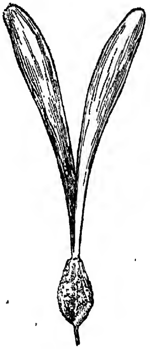


FIG. 309. Winged fruit of Gyrocarpus.

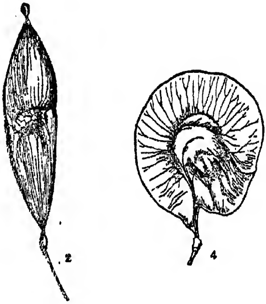


FIG. 310. Fruits with wings. 2, Ailanthus, and 4, Pterocarpus.

Just as we find variations to a large extent in other parts of plants, we meet with a very great amount of variation in fruits and seeds also. For instance, we find seeds so small that we could hardly see them with the naked eye, as in Orchids and Striga ; and we also find massive seeds as in the Coconut and seeds of all dimensions ranging between these extremes. Again as regards colour also we find a great range in variation. In the matter of structure and appendages it is equally so. These variations in different directions cannot be a matter of mere accident, and they must have some significance. The significance becomes obvious, if we bear in mind the sheer necessity for the wide dispersal of seeds. Without

special adaptations and special agencies, dispersion is a matter of difficulty. Variation in all directions is a positive advantage.

Let us now consider some examples of fruits and seeds and see if all that is said of them is true. The fruits of *Gyrocarpus Jacquini*, a common tree of the plains, are interesting. This fruit consists of a round or ovoid portion enclosing the seed and two long wings varying in length from two to three inches. (See fig. 309.) During the hot weather this tree bears heavily. Whenever there is a wind, a large number of fruits are detached and they are wafted in the air. They are carried to long distances, because the fruit does not fall down as long as the wind lasts. On account of the wings the fruits keep on spinning round and round like a top or a shuttle-cock shot in the air. The relation existing between the spread of the wings and the size and weight of the seed is such that it is capable of sailing in the air for sometime at least, before it comes down. On one occasion the fruits of this tree were found nearly a mile away from the tree. From this example we clearly see that winged seeds are specially meant for dispersal by wind. We have in this presidency many examples of winged fruits, and all of them belong either to trees or lofty climbers. The possession of wings in the case of winged seeds of trees is not a matter of mere accidence. It is developed solely as a means of dispersal. If the presence of wings were accidental and the dispersal merely its result, we should expect to find winged seeds in all kinds of plants. For instance, we should have such seeds in the case of even low herbs, and aquatics. We do not of course come across winged seeds on low herbs, because they would obviously be of no use. Though the winged seeds of trees are capable of sailing high in the air, they cannot do so low down, and some height is necessary. As they are usually heavy they cannot be lifted from low situations for want of enough force on the part of the wind. We know that the force of the wind goes on increasing with the height. In the case of tall trees the height is an advantage, because the winds are likely to blow more strongly there and the seeds are not likely to be impeded in their travel and they escape being entangled.

Of the numerous winged fruits occurring in the flora of this part of India, those of Ailanthus, Holoptelea, Combretum, Pterocarpus, Pterolobium, Hardwickia, Hopea, Shorea and Dodonæa are common enough. As examples of seeds with wings we may mention the seeds of Cedrela, Soymida, Tecoma, Dolichandrone, Oroxylum and Mahogany.

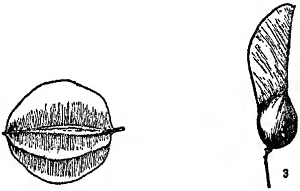


FIG. 311. Winged fruits of 1, Combretum and 3, Pterolobium.

From the fact that winged seeds are confined to trees it must not be supposed that herbs do not make use of the wind for dispersal of their fruits or seeds.

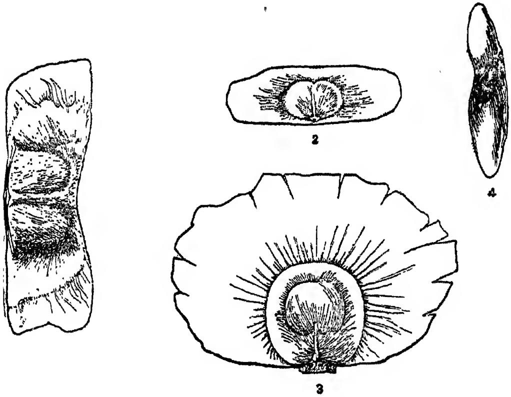


FIG. 312. Winged seeds of 1, Dolichandrone; 2, Tecoma; 3, Oroxylum and 4, Cedrela.

Just as wings are specially good for seeds of trees so plumes are best suited for low herbs and shrubs. The parachute-like pappus hairs of the Tridax achenes are far more

efficient for their dispersal than wings. For lifting the fruits from low situations the plume is the best possible adaptation. It is this appendage that has enabled the plant Tridax to

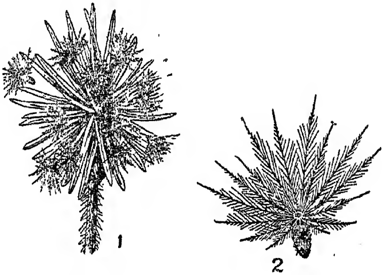


FIG. 313. Pappus bearing achenes of *Tridax procumbens*. 1, flower head with achenes; 2, a single achene.

establish itself everywhere. This plant was introduced into this country some years ago and within a short space of time it has managed to spread everywhere. It was not at all common at higher altitudes fifteen years ago, and now it is as much at home there, as it is on the plains. Examples of plumed fruits and seeds are afforded in abundance by the families Compositæ and Asclepiadeæ and also Apocynaceæ. We all know that plants of these families are very widely distributed and we find some species or other of them almost everywhere. The plume or hairs are from the calyx in the case of the achenes of the Compositæ; but in the case of the Asclepiadeæ and Apocynaceæ it is the seeds

FIG. 314. Plumose achenes of *Vernonia cinerea*.

that bear the tufts of hair (see fig. 301); so also is the case with the Cotton seed and that of Hibiscus micranthus. Clematis furnishes examples of achenes whose styles are not only persistent, but are also provided with hairs to facilitate their dispersal. Both in winged and plumed fruits we generally find only one seed.

We have several plants possessing small seeds with special devices to bring about dispersal. The seeds are numerous in such plants, and they lie loose at the bottom of a capsule which is usually borne at the ends of stiff upright elastic peduncles. Every gust of wind will shake the fruit, and on account of the stiffness of the stalk there will be a sudden rebound to the original position which must lead to the scattering about of some seeds at least. Capsules, intended to shed their seeds thus, open only at the top either by means of pores or by very short longitudinal slits. This arrangement prevents the shedding of all the seeds at once and in one place. Winds do not blow always with the same force and so the seeds have the chance of falling in different places. The introduced Mexican poppy, *Argemone mexicana*, is an excellent example to illustrate this fact. The single-celled capsules of this plant are at the extremities of stiff branches and the dehiscence is by means of short slits at the top. The seeds are small and every time there is a wind a few seeds are shot forth, sometimes near and at other times a little farther, according to the nature and force of the wind.

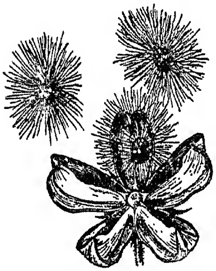


FIG. 315. Fruit and hairy seeds of *Hibiscus micranthus*.

When a solid round body begins to decrease in volume its surface will also diminish relatively to the mass, but the rate with which the volume decreases is greater than the rate of the diminution of the surface. So a body when it reaches a certain point of smallness the surface that it possesses in relation to its weight will be proportionately more, than when it is larger. The seeds of Orchids are very small

and they have sufficient surface to enable them to remain in air sufficiently long. And when winds blow, such seeds may travel very long distances.

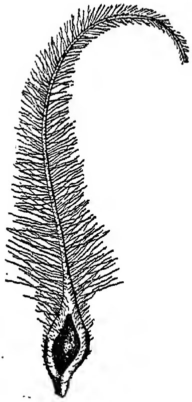


Fig. 316. Achene of Clematis.

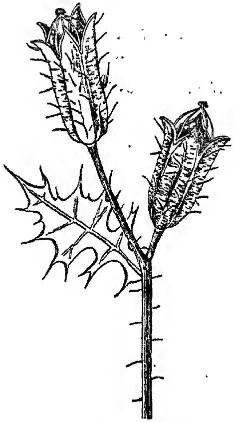


Fig. 317. Capsule of Argemone.

Several dry fruits scatter their seeds to long distances by their bursting. The fruits of Canavalia and those of several other leguminous plants hurl their seeds to long distances by the sudden breaking of the valves and their twisting in the opposite directions. The seeds of Canavalia are hurled to a distance of ten to fifteen feet when the valves of the fruit burst open. The cocci of the Castor fruit are also thrown several feet when the fruit

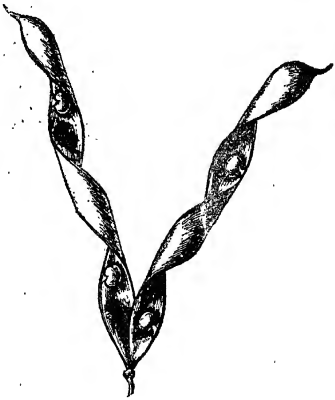


Fig. 318. A legume bursting and hurling its seeds.

dries and breaks. Euphorbias scatter their seeds in the same manner. The fruits of *Hura crepitans* burst with a noise almost as loud as the report of a Chinese cracker. As further examples of fruits that expel their seeds by explosion, we may mention those of Impatiens and of some species of Acanthaceæ. The fruits of *Ruellia prostrata* have at their tips a specialised spot which when wetted leads to the sudden bursting of the capsules. If we place these capsules in water, as soon as the tip becomes wet they burst with a noise scattering the seeds on all sides. We can feel the force with which it bursts, by putting these capsules into our mouth.

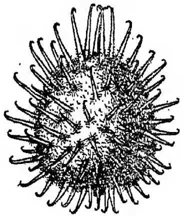


FIG. 319. Hooked fruit of *Triumfetta rhomboidea.*

We have now to consider those fruits that are provided with hooks and spines. These are undoubtedly meant for dispersal by animals. The fruits get entangled in the fur of animals, by means of the hooks. If we examine our clothing, after a ramble through a scrub or a waste place, we find many kinds of fruits sticking on to them. The fruits that commonly stick on to our clothes thus are those of Achyranthes, Pupalia, Triumfetta, Zornia and Desmodium. Amongst herbs and shrubs there are many plants that bear hooked fruits. The fruits of the plants *Urena lobata, U. sinuata, Xanthium strumarium*, Bidens and Mimosa are also hooked.

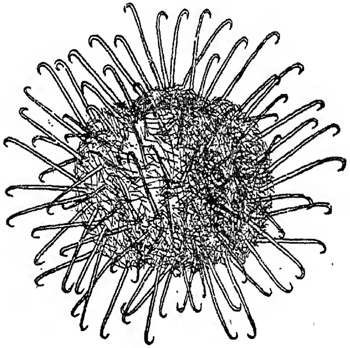


FIG. 320. Hooked fruit of *Triumfetta pilosa.*

In all these cases the hooks are small and they are directed on all sides. As most of these fruits are small, they do not seem to cause any inconvenience to the animals to whose skins they cling. A most remarkable example of a hooked fruit of a formidable nature is mentioned by Sir John

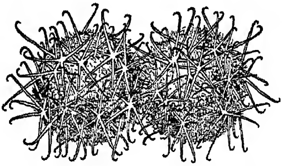


FIG. 321. Hooked fruits of Pupalia. The hooks are imperfect flowers.

Lubbock. The South African genus Harpagophytum produces fruits that are really formidable on account of the woody spines borne by the pericarp of the fruit. These

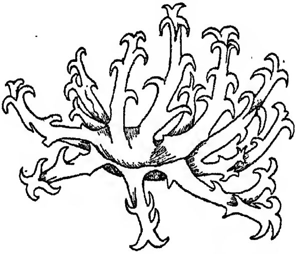


FIG. 322. The fruit of the Grappling plant (Harpagophytum) (after Lubbock).

spines called "grapples" are woody and are about an inch long, and are provided with barbs turned in various directions. These fruits are said to roll about and become attached to the skin of lions. The unfortunate animal in its attempts to get rid of this fruit, sometimes gets it into its mouth and then it dies.

The hooks or spines are developed from various parts. In the fruits of Urena, Triumfetta, Zornia and Cullenia the hooks arise from the pericarp.

In Bidens the pappus horns are barbed. In some cases the perianth persists along with the fruit, and the tips

of their lobes are spinescent, as in Achyranthes. Sometimes imperfect flowers become hooks as in Pupalia. Even bracts sometimes develop into hooks as in *Tragus racemosus*, or these are spinescent as in *Amarantus spinosus* and *Echinops echinatus*. In the case of *Xanthium strumarium* the achenes are enclosed by the involucral bracts, and these bear hooked spines. This plant is really a troublesome weed, as it spreads widely and rapidly. In South Africa the fruits of Xanthium are said to have caused so much damage to the wool, some years back, as to necessitate a legislation to extirpate this weed. Even in this country it sometimes monopolises large areas, especially wet clayey situations and then it is not easy to get rid of it.

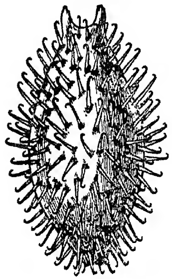


FIG. 323. Fruit of Xanthium

We have also a few species of plants producing sticky glands which help the fruit in their dispersal by sticking to the feathers of birds. We have such fruits in Pisonia, Boerhaavia, Siegesbeckia and *Plumbago zeylanica*.

The dispersion of hooked and sticky fruits is brought about by the agency of animals, and the animals do not do this consciously. But in the case of fleshy fruits, animals deliberately go in search of them and eat them. As already pointed out, the seeds in the fleshy fruits are all hard, if the fruit is a berry, and the hardness is due to the thickening of the seed-coat. If they are drupes then the seeds remain within the stony endocarp. In both these cases the seed possesses an indigestible covering. Around the hard covering is the sweet

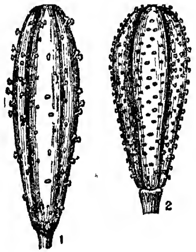


FIG. 324. Boerhaavia fruits, 1, fruit of B. *repanda*; 2, fruit of B. *repens*.

luscious edible fleshy part. All fleshy fruits are highly coloured, after the seeds are fully formed and ready for dispersion. But in young and unripe fruits the pericarp is generally green and the fleshy part will invariably be very unpalatable. Fruits get their characteristic colour only when they are fully mature and ripe. The distribution of unripe fruits is in no way beneficial for the plant, and as a safeguard against this sheer waste the fleshy part remains unpalatable, until the seeds are fully developed and are ready for travel. This mode of dissemination is very common and it must rank very high among the different modes of dispersal, and is second only to dispersion by wind.

Some seeds get dispersed on account of their arils, or strophioles. The seeds of *Pithecolobium dulce* have very well developed arils which are sweet when the seeds are mature. Then birds peck at the aril and devour it dropping the seed in various places. (See fig. 307.)

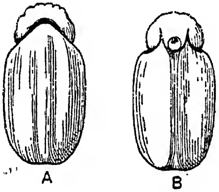


FIG. 325. Jatropha seed A, back and B, front view.

There are some seeds which depend for their dispersal on deceptive appearances. They resemble insects and are consequently picked up by certain insectivorous birds, but only to be thrown away as being useless and this is exactly what the seeds need. Instances for this type of seed are provided by the castor and Jatropha seeds.

We have instances of plants securing dispersal by the whole of the inflorescence being carried by the wind over long distances. The seashore grass *Spinifex squarrosus* is disseminated by its large round ear-heads that roll along the ground with the winds.

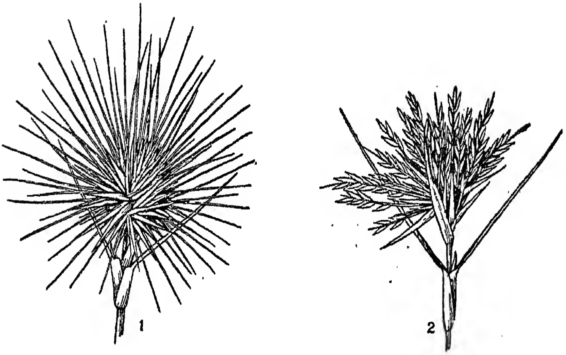


FIG. 326. The inflorescence of Spinifex.
1, female ; 2, male.

Lastly, we have also fruits depending on water for their dispersal. As examples, we need only mention the Coconut, the Seychells Double Coconut, the top-like receptacle of Lotus which carries the fruits, the fruit of *Cerbera Odollam* and that of *Entada scandens*. It should be remembered that the fibrous pericarp of the Coconut though useful for dispersal by means of water, it may have other uses, especially in connexion with germination.

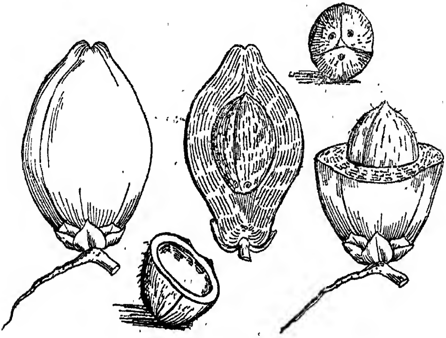


FIG. 327. The Coconut.

CHAPTER XX

VEGETATIVE REPRODUCTION

REPRODUCTION is a most necessary process in the life of a plant and for most plants the production of seed is of paramount importance, for without it the extension and distribution of species is well nigh impossible. In the case of higher plants the obvious method of propagation is by means of seeds that are produced by sexual reproduction, a process very complex in character, inasmuch as it involves the fusion of very specialised cells called **gametes**.

It must not be thought that this is the only method by which plants multiply and get dispersed. Instead of always adopting this most complicated form of propagation, plants sometimes have recourse to other modes of reproduction. There are many ways by which they reproduce themselves, in all of which the fusion of the gametes is dispensed with and only portions of the vegetative organs are concerned. These processes are simple in character and are merely the results of growth. Hence all these processes go by the name **Vegetative Reproduction.**

We all know that some plants are propagated by means of small bits of stems. For instance the plants *Clerodendron phlomoides*, *Convolvulus arvensis*, *Cynodon dactylon* and a host of other plants propagate themselves in this manner. These plants have an extensive system of underground stems that are very brittle. Even small bits of these branches are capable of growing into separate plants. It is this special feature of these plants that makes them most troublesome weeds. We have many species of plants that propagate themselves vegetatively, even in a wild state. Many plants have lost the power of producing seeds under cultivation, and consequently they can be propagated, only by vegetative reproduction. The methods of vegetative propagation are as varied, as are the means for the dispersal of seeds.

Plants having a creeping habit similar to that of *Centella asiatica*, flourish everywhere. In all such plants

branches creep along the surface of the ground producing roots at the nodes. These plants may go on increasing and establishing new colonies in any number and occupy within a short time considerable areas, because of the capacity of becoming independent plants possessed by the creeping branches, when they get severed from the older portions either by decay, or accident.

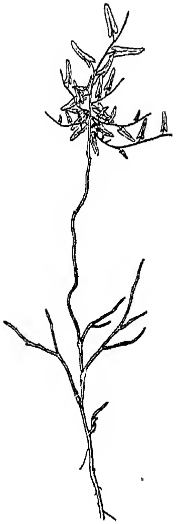


FIG. 328. *Convolvulus arvensis* L., showing the underground stems.

There are many plants whose stems are mostly subterranean, and the main work of these underground stems may be said to be the propagation of their kind. Subterranean stems in which reserve food material is stored in abundance, such as, rhizomes, corms and bulbs, are specially adapted to serve this purpose. The underground branches, like other organs of a form and structure. There are plants whose underground stems differ very little from the ordinary aerial branches. For instance, in the Hariali grass, the stolons are white, bear adventitious roots and have scale-leaves instead of green foliage leaves. There is no visible storage of food material. In the grass *Panicum repens*, we have an example of a plant whose underground parts consist of both stolons and rhizomes. Several species of Cyperus develop stolons, as well as tubers or bulbs. Instances there are in which the whole of the shoot-system consists of rhizomes. Further modifications are the bulbs, tubers, and corms. All these modifications are undoubtedly due to the storage of reserve food material.

When the underground stems are stoloniferous or rhizomic in character some of them turn up, come above the

surface and develop into ordinary leafy branches. These aerial branches remain connected with the underground stems and depend upon them for their development, until they become fully established. When once these aerial branches have become fully established, they are capable of becoming independent plants. On account of the continued connexion and the presence of roots storage of reserve food becomes unnecessary in these cases. From the underground stems large number of branches may come up, but amongst them those developing from the terminal bud and lateral buds in its proximity are usually more vigorous than those arising from the lateral buds lower down.

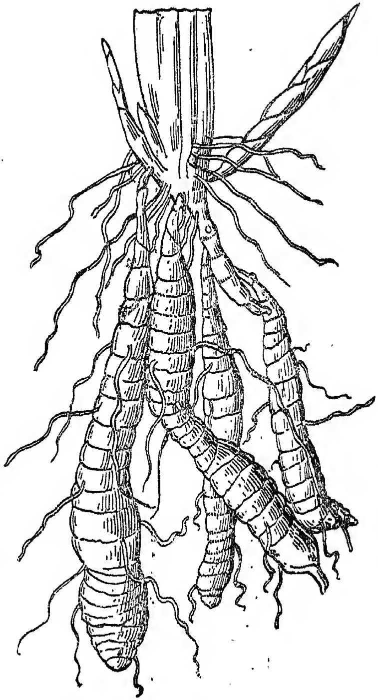


FIG. 329. Rhizomes of Arrowroot.

Now coming to the very much modified stems, tubers, corms and bulbs these are much better fitted for vegetative propagation than rhizomes and stolons, as the abundant storage of reserve food is a positive advantage to start their growth. In these cases the separation from the main plant may take place long before the appearance of the daughter plants.

As an example we may mention the Potato. In the Potato plant some branches develop underground, grow and

become thickened at their ends forming tubers. These tubers are capable of growing into separate plants when detached from the parent plant. Sometimes and in some plants the axillary buds in the aerial branches develop into aerial tubers. For instance, in many cultivated species of Dioscorea aerial tubers are very common. They all drop down and then grow into separate plants. In Agaves and Chlorophytums bulbils appear in the inflorescence, and they drop down and develop into separate plants.

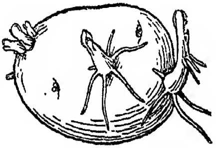


FIG. 330. Potato tuber germinating.

A corm, as for instance in Amorphophallus or Synantherias, represents the whole of the shoot system of the plant. The reserve food material, instead of being stored in the lateral branches, is allowed to accumulate in the main stem, and the lateral branches remain as small buds on the surface of the corm. All the buds found in a corm are capable of developing into new corms in their turn, although it is the terminal bud which usually grows and becomes the new corm. Generally corms of two or three seasons remain together. (See figs. 104 to 106.) In the corm of Amorphophallus there are no scale-leaves; but sometimes a corm may be covered by a few scales, or the scales may be many and the stem also somewhat massive, as in the tuberose, making it intermediate between a bulb and a corm. Such structures as these go by the name "solid bulbs" amongst horticulturists. From this to the bulb proper is an easy gradation. In a bulb the axis is not very conspicuous a

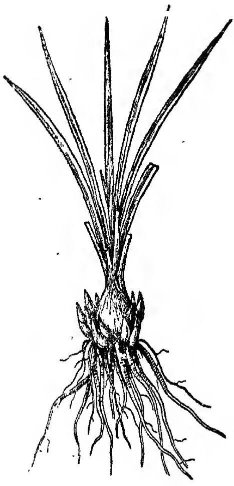


FIG. 331. Polianthes. Note the daughter bulbs.

the scales are numerous. In bulbs, whether solid or ordinary, we find many daughter bulbs,—really axillary buds, and by these they get multiplied. (See figs. 331 and 332.)

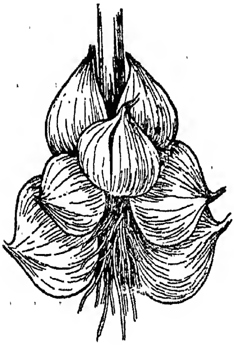


FIG. 332. Onion bulbs.

In rare instances even leaves give rise to buds which usually develop into plants later on. Adventitious buds develop at the margins of leaves of *Bryophyllum calycinum* and in *Scilla indica* at the apex of the leaves. When injured, buds make their appearance in the leaves of Begonia.

Even roots, as has already been mentioned in another chapter, are capable of producing shoots when cut. This affords another means of vegetative propagation.

In addition to the various methods of vegetative reproduction, many a plant still possesses the power of regenerating the parts that are lost. This tendency is taken advantage of in the propagation of rare and valuable varieties of plants. It is this property that makes it possible to raise plants by grafting, by layering and by means of cuttings.

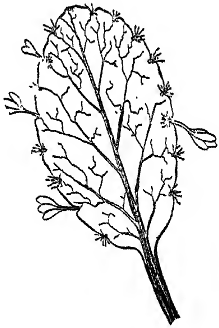


FIG. 333. Bryophyllum leaf with adventitious buds.

Very often one comes across plants that are able to propagate themselves by the production of seeds, as well as by the vegetative method of reproduction, by the one or the other of these two methods according to circumstances. It may be that the plant is capable of bearing seeds in abundance and yet it sometimes may adopt the vegetative method of reproduction.

From this it is clear that there should be certain factors which determine the kind of reproduction to be adopted by the plant, when it is capable of both sexual and asexual reproduction. From experience we know that all the conditions favouring large accumulations of food stuff and vigorous growth tend to make a plant grow vigorously and develop its vegetative parts. And then such a plant tends to multiply itself by vegetative reproduction. When conditions are not favourable for a vigorous growth, plants resort to the formation of seeds. We often see plants growing in open dry places running into flower and seed.

The nature of the offspring of a plant will vary with the kind of reproduction. If the offspring has resulted from vegetative reproduction, they will maintain the characteristics of their parent plant. The vegetative method of propagation will, therefore, enable any one to propagate a variety or form without any change in its character, and make it occupy the land quickly. But, it must be remembered that plants produced by vegetative propagation are less able to withstand changes in their environments than those derived from seeds. With plants produced by the sexual method, it is far otherwise. In this case the fusion of cells from two different individuals, which is the chief feature of this process, changes the character of the offspring in a profound manner. Generally the offspring differ from their forbears in some respects at least. Some of the offspring may be like one parent, some like the others and some others may differ from both. No doubt the young plants may resemble the parents in a general way, but on close inspection differences also will become apparent. This tendency is an advantage, if new varieties are required, and in nature it leads to the formation of new plants. To make this point clear we may take the case of the propagation of the mango. If one wishes to have mango plants of a particular variety in large numbers, he should adopt the vegetative propagation, but if the object is to obtain different varieties he must have recourse to seeds that result from sexual reproduction.

CHAPTER XXI

PRINCIPLES OF CLASSIFICATION

AMONGST plants, the spermaphyta or seed-plants represent the most highly organized group. It includes a very large number of individuals (about 120,000 now), with an endless variation in their structure and mode of life. To get an insight into the forms of plants that exist, some sort of grouping of plants or classification is necessary, otherwise it is impossible to make any progress in acquiring the knowledge of plants.

By comparing plants with one another we find resemblances as well as differences, in varying degrees, and it is usual to speak of the resemblances as **affinities**. It is obvious that plants which are alike in several characters must have had a common origin. For example, the individual plants of a crop are all alike in many respects, because they are the offspring of one kind of plant. So affinities show the relationship amongst plants.

The earliest system of classification, which was in use until the middle of the last century, is the Linnean system of classification based upon the single characteristic, the number of the stamens in a flower. This system, though most convenient for practical use, is defective and unsatisfactory, because of its arbitrary and artificial nature. When plants are grouped, taking into consideration only a single character, we are obliged to bring together plants having no real affinities, and keep apart those closely related. The Linnean system is now superseded by others, more natural because a larger number of characters form the basis for classification. The main aim of the modern systems of classification is to express the relationship between different plants. Therefore, as many characters as possible are taken into consideration. And it is only then that the exact relationship could be determined.

There are two Natural systems of classification now in use, and they are (1) the system of Engler and (2) the system

of Bentham and Hooker. The former is largely in use on the continent of Europe, while the latter is the standard one in Great Britain and India. Therefore, in this chapter we shall follow Bentham and Hooker's system.

Flowering plants with a closed seed vessel or Angiosperms are divided into **Dicotyledons** and **Monocotyledons.**

Dicotyledons, as the name implies, have two cotyledons in their seeds. Flowers are generally tetra- or penta-merous and the leaves are net-veined. A well marked tap-root and a stem with secondary growth are also the characteristics of this class.

Monocotyledons, on the other hand, have only one cotyledon intheir seeds. Flowers are trimerous and leaves are parallel-veined. The stem, as a rule, does not increase in thickness and there is no tap-root.

These classes are further subdivided into **sub-classes, Series** and **Natural Orders** or **Families**, as shown towards the end of this chapter.

For purposes of classification plants of a particular kind are said to be of one **species** and species are grouped together into a large group, the **genus**; and the genera are further grouped into **Families** or **Natural Orders.**

We shall try to render all these points quite clear by means of certain examples. Let us select a common plant such as the Bendai or the Okra plant. All the plants raised from the seeds of a Bendai plant are of the same kind and so we consider this kind to be a species and the scientific name of this species is *Hibiscus esculentus*, L. On comparing this plant with three other kinds or species, Gogu, Shoe-flower and *Hibiscus vitifolius*, L., we find that all these species are similar in certain characters, especially in the parts of the flower. These common characters are as follows:—The stamens form a monadelphous tube, with kidney-shaped unilocular anthers, enclosing a superior ovary and a filiform style which ends in five stigmatiferous branches; petals are five, free, contorted and adherent at the base to the staminal column; and the calyx is monosepalous with an epicalyx of bracts at its base. These characteristics constitute the diagnosis of a genus and so all plants possessing the above characteristics should be brought under this genus, and the

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name of the genus is *Hibiscus*. These four plants that we have chosen as examples belong to the same genus, Hibiscus. We have about a dozen species under this genus growing in this part of India. The scientific names of the plants, Bendai, Gogu and Shoe-flower are respectively *Hibiscus esculentus*, *Hibiscus cannabinus* and *Hibiscus Rosa-sinensis*.

We have a number of other plants resembling the *Hibiscus* in certain features. For instance, the Portia tree, the cotton plant and the plant *Abutilon indicum*, G. Don., resemble the *Hibiscus* in certain respects. All these plants agree with the genus *Hibiscus* in having a staminal tube with unilocular anthers, free contorted petals, adnate with the staminal column at its base and a monopetalous calyx. On account of these common characteristics, we are justified in grouping all these plants, as well as the species of *Hibiscus* mentioned above, under one higher group, the Family or the Natural Order. The name of the Natural Order in this case is *Malvaceæ*.

It would, perhaps, conduce to clearness, if we set forth all these facts in a tabular form so as to indicate the limits of species, genus and the Natural Order—

All plants having flowers with monosepalous calyx and free contorted petals, adherent at base to the staminal tube with unilocular anthers belong to the family *Malvaceæ*.	*Malvaceæ*.

Plants of the family Malvaceæ may further be subdivided into *genera* and *species* as shown below :—

Style branched at the free end—

Epicalyx present—

bracts five or more ... ... style branches five ... ... ovary five or many-celled ...	*Hibiscus*.
bracts three ; style lobes three ; ovary three or four-celled.	*Gossypium*.

Epicalyx not present—

style branches and cells of the ovary twenty or more.	*Abutilon*.
style not branched at the free end.	*Thespesia*.

species of the genus Hibiscus.

Flowers, large, showy—
Petals yellow—
, angled sharply, seeds } *H.*

fruit small, but with close-set harsh bristles; calyx with glands outside. } *H. cannabinus.*

fruit long; calyx spathaceous ... *H. esculentus.*

Petals red—
fruit not formed ... ... *H. Rosa-sinensis.*

Flowers, small—
Petals white—
fruit small and round; seeds cottony. } *H. micranthus.*

SYSTEM OF CLASSIFICATION ACCORDING TO BENTHAM AND HOOKER.

CLASS—DICOTYLEDONS.

Sub-class I Polypetalæ—(Flowers usually with both sepals and petals and the latter distinct and not united.

Series (1) Thalamifloræ.—Sepals and petals quite distinct, stamens hypogynous and ovary superior.

Series (2) Discifloræ.—Sepals distinct or united, free or adnate to the ovary: stamens hypogynous: a disc is present; ovary superior.

Series (3) Calycifloræ.—Sepals united, free or adnate to the ovary; stamens perigynous; ovary superior or inferior.

Sub-class II Gamopetalæ.—(Flowers usually with both calyx and corolla and the latter always monopetalous.)

Series (1) Inferæ.—Ovary inferior and stamens equalling the petals in number.

Series (2) Heteromeræ.—Ovary superior; stamens equal to petals, more or indefinite.

Series (3) Bicarpellatæ.—Ovary superior; stamens equal or less than the corolla lobes; carpels two.

Sub-class III. Incompletæ.—(Monochlamydæ.) (Flowers with a single whorl of perianth, i.e., the calyx.)

Series (1) **Curvembryeæ.**—Ovary with solitary ovules; embryo curved in floury endosperm.

Series (2) **Multiovulatæ.**—Ovary with indefinite ovules.

Series (3) **Micrembrye.**—Ovary with solitary ovules in the cells apo or syncarpous; embryo very small with endosperm.

Series (4) **Daphnales.**—Ovary of one carpel with one or more ovules, perianth regular perfect and stamens perigynous.

Series (5) **Achlamydosporeæ.**—Ovary unilocular, 1 to 3 ovuled but ovules not clear until after fertilization.

Series (6) **Unisexuales.**—Flowers unisexual, ovary one carpel or syncarpous; ovules solitary or two in each cell; sepals reduced or absent.

CLASS—MONOCOTYLEDONS.

Series (1) **Microspermæ.**—Inner perianth petaloid; ovary inferior with three parietal placentas; seeds very minute.

Series (2) **Epigynæ.**—Perianth partly petaloid; ovary inferior and endosperm plenty.

Series (3) **Coronarieæ.**—Inner perianth petaloid, ovary free, superior, endosperm present.

Series (4) **Calycinæ.**—Perianth sepaloid; ovary superior.

Series (5) **Nudifloræ.**—No perianth; ovary superior.

Series (6) **Apocarpæ.**– Perianth one or two whorls or absent; ovary superior apocarpous.

Series (7) **Glumaceæ.**—Flowers single, axillary in the axils of bracts; no perianth; ovary one-celled and one-ovuled.

NATURAL ORDERS * GROUPED ACCORDING TO BENTHAM AND HOOKER'S SYSTEM.

DICOTYLEDONS.

POLYPETALÆ—

(1) **Thalamifloræ**—

Anonaceæ.
Nymphæaceæ.

POLYPETALÆ—*cont.*

(1) **Thalamifloræ**—*cont.*

Cruciferæ.
Capparideæ

* Only those described in the next chapter are included here.

POLYPETALÆ—*cont.*

(1) Thalamifloræ—*cont.*

Violaceæ.
Polygalaceæ.
Portulacaceæ.
Malvaceæ.
Sterculiaceæ.
Tiliacæ.
Linaceæ.
Geraniaceæ.

(2) Discifloræ—

Rutaceæ.
Meliaceæ.
Rhamneæ.
Ampelideæ.
Sapindaceæ.
Anacardiaceæ.

(3) Calycifloræ—

Leguminosæ.
Combretaceæ.
Myrtaceæ.
Cucurbitaceæ.
Aizoaceæ.
Umbelliferæ.

GAMOPETALÆ—

(1) Inferæ—

Rubiaceæ.
Compositæ.

(2) Heteromeræ—

Sapotaceæ.

(3) Bicarpellatæ—

Apocynaceæ.
Asclepiadeæ.
Boragineæ.
Convolvulaceæ.
Solanaceæ.
Scrophularineæ.
Pedalineæ.
Acanthaceæ.
Labiatæ.

INCOMPLETÆ—

(1) Curvembryæ—

Amarantaceæ.

(2) Unisexuales—

Euphorbiaceæ.
Urticaceæ.

MONOCOTYLEDONS.

Series (1) **Microspermæ**—Orchideæ.
Series (2) **Epigynæ**—Scitamineæ, Amaryllideæ.
Series (3) **Coronarieæ**—Liliaceæ, Commelinaceæ.
Series (4) **Calycinæ**—Palmæ.
Series (5) **Nudifloræ**—Aroideæ.
Series (6) **Glumaceæ**—Cyperaceæ, Gramineæ.

CHAPTER XXII

DESCRIPTION OF NATURAL ORDERS

ANONACEÆ

FOR this family the *Custard-apple* (*Anona squamosa*, L.) may be taken as a type. This is a small tree branching freely with leaves, arranged bifariously on the twigs. Leaves are simple, alternate, exstipulate, shortly petioled, oblong, entire, dark green above and slightly glaucous beneath.

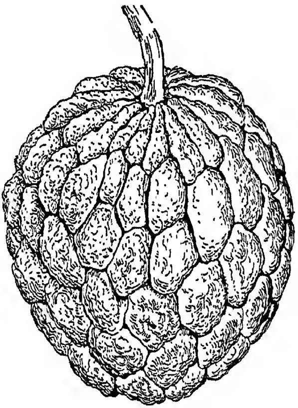


FIG. 334. Fruit of *Anona squamosa*, L.

Flowers arise singly from the leaf axils and the flower consists of three small triangular membranous sepals, valvate in bud, three petals, indefinite stamens and a superior ovary of many carpels. The petals are valvate in bud, fleshy, thick and somewhat triangular in section, narrow oblong and concave below. Stamens are spirally and closely packed on the prominent conical receptacle and hypogynous; filaments are very short; anthers long, two-lobed, and crested with the dilated end of the connective. Ovary consists of many carpels closely packed.

Fruit is a berry consisting of several fleshy carpels, all fused together in one mass. Seeds are black, polished and oblong and possess endosperm which is in the form of folds (ruminate endosperm).

Anona reticulata, L., or the Bullock's-heart is another common tree under cultivation. This differs from the Custard-apple only in certain respects. Flowers are clustered in groups, instead of solitary, and the areolation on the surface of the fruit is not quite so distinct as in *A. squamosa*, L.

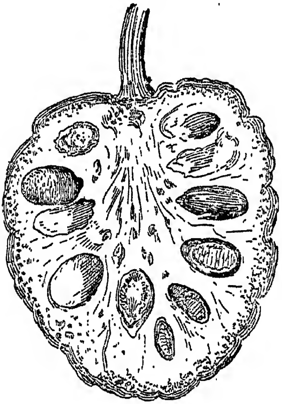


FIG. 335. Fruit of *Anona squamosa*, L., longitudinal section

Polyalthia longifolia, Benth., is another common avenue tree of this order. Leaves are lanceolate with undulate margins, shining and studded with pellucid glands. Flowers arise from old branches in umbels, or short racemes. Petals are thin six, in two whorls of three each. Fruit consists of free carpels.

Characters of the Family.—Plants belonging to this order are trees or scandent shrubs. Leaves are simple, alternate, ex-stipulate, short-stalked, entire and generally bifarious.

Flowers are solitary, fascicled, umbelled or racemed. Sepals are three, valvate in bud and small. Petals are either six (in two series of three) or three. Stamens are numerous ; hypogynous, closely and spirally packed on the receptacle ; filaments are short, anther linear and usually crested by the

dilated end of the prolonged connective. Ovary is superior consisting of closely packed carpels which are usually free (fused in Anona). Fruit is fleshy, of free carpels except in Anona. Seeds have ruminate endosperm.

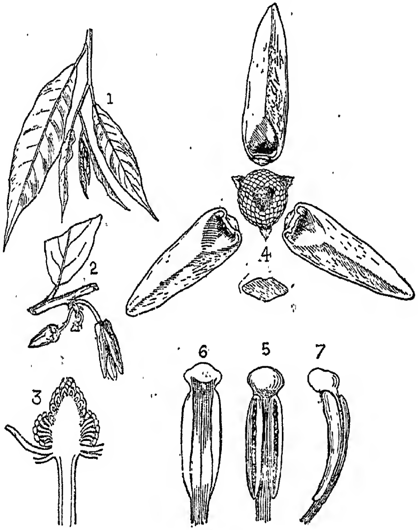
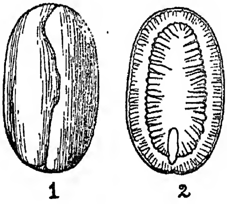


FIG. 336. Floral parts of *Anona reticulata*, L. 1, branch with young leaves; 2, flowers; 3, stamens and the pistil; 4, parts of the flower; 5, 6, 7, front, back and profile views of stamens.

This family is completely tropical. Other genera commonly found in South India, are Uvaria, Saccopetalum and Miliusa.



. 337. Seed of *Polyalthia longifolia*, Benth. 1, entire seed 2, section of seed showing the embryo and ruminated endosperm.

The Water-lily and Lotus are the representatives of this family. Both are aquatics and are met with in tanks and ponds all over South India.

Nymphæa pubescens, Willd., or the Water-lily has a short underground stem and large leaves on very long stalks. The leaf blade is somewhat round in outline with a deep sinus at the base, attached to the stalk peltately, and floats on the surface of the water with the part where the petiole joins it being slightly raised and higher than the other parts. The lower surface of the blade is reddish and the spongy veins are very prominent and the upper surface is green, smooth and cannot be wetted with water.

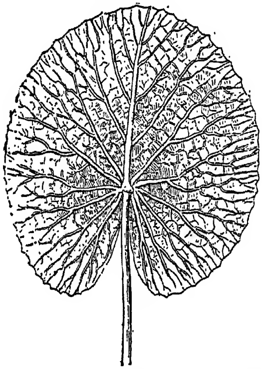


FIG. 338. Leaf of *Nymphæa pubescens*, Willd.

Flowers are solitary on long scapes, floating. Sepals are four, oblong. Petals are unequal, twelve or more, oblong, white or deep red. Stamens are about 35 to 40 or more; filaments are flattened at the base, the outer more so than the inner; anthers are introrse, without appendages. Ovary consists of many carpels fused with the fleshy receptacle.

Fruit is a soft spongy berry with 12 to 15 or more cavities lined with seeds. Seeds are somewhat globular, covered with tubercles appearing as lines and are enclosed by a saclike aril.

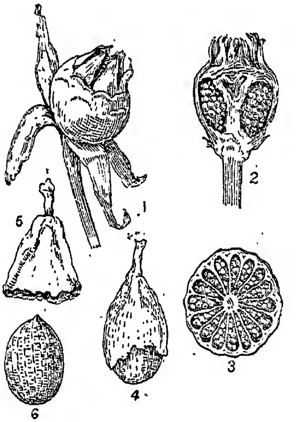


FIG. 339. *Nymphæa pubescens*, Willd. 1, fruit; 2, longitudinal and 3, transverse sections; 4, arillate seed; 5, 6 aril and seed separated. (4, 5 and 6 magnified and 1, 2 and 3 reduced.)

FIG. 340. *Nelumbium speciosum*, Willd.

The Lotus or *Nelumbium speciosum*, Willd., is another well-known plant of this family growing in temple tanks. It has a creeping and branching stem with roots at the nodes. Leaves are very long-stalked and the blade is round, raised above water and cup-shaped in the middle. Flowers are solitary, large, on long peduncles. Sepals are four or five. Petals are 15 to 20 or more, white or pink, unequal and deciduous. Stamens are many with club-shaped appendages to the anthers. Carpels are ten to twenty separately sunk in the top shaped receptacle.

Fruit consists of the top-shaped receptacle in which the ripe carpels are imbedded.

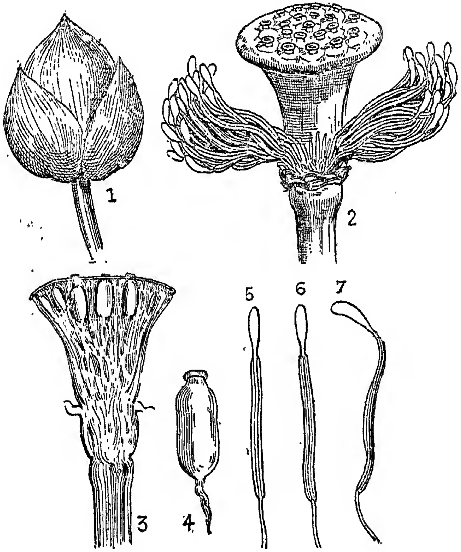


FIG. 341. *Nelumbium speciosum*, Willd. 1, flower bud; 2, essential parts, stamens and pistil; 3, the gynæceum cut through; 4, carpel; 5, 6, 7, stamens.

Characters of the Family.—Plants of this order are all aquatics with large leaves and flowers borne on long stalks, which are usually spongy on account of large air spaces. The sepals are usually four or five, free. Petals are many,

unequal, free ; stamens are indefinite with flattened filaments. The ovary consists of many carpels that are either fused with the receptacle or free and immersed in it. Fruit is a berry. Seeds are arillate or not.

CRUCIFERÆ.

The Mustard plant, *Brassica juncea*, L., serves as a good example of this family. It is an annual with sessile, pinnately lobed leaves and long terminal racemes of yellow flowers. The racemes are at first corymbose and the axis elongates later, when fruits are formed.

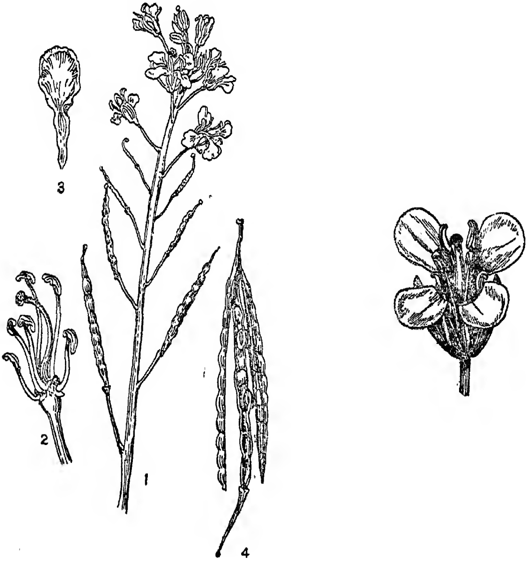


FIG. 342. *Brassica juncea*, L. 1, raceme ; 2, stamens and pistil ; 3, petal ; 4, fruit (siliqua) ; 5, flower.

Flowers are generally without bracts. There are four narrow green sepals in two whorls, and the two lateral sepals of the inner whorl are slightly bulging at the base on account of the two glands opposite to them on the receptacle. Petals

are free like the sepals, clawed, bright yellow and are crosswise in one whorl. Stamens are six, tetradynamous ; the two shorter stamens are opposite the lateral bulged sepals, and there are two glands one near each of these stamens. The ovary is superior, of two carpels with parietal placentation. At first though unilocular a false septum is formed later, and hence the fruit is two-celled. Fruit opens by two valves separating from below and leaving the septum with seeds on. Seeds are black, small.

This order is very well represented in temperate regions, and in the tropical regions very few species occur. In South India Cardamine and Capsella are the only genera occurring in a wild state on higher elevations. Other plants of this order, such as the Radish, Turnip, Cauliflower, Cabbage, Nolkhol are all usually cultivated.

Fig. 343. Radish. 1, inflorescence ; 2, flower ; 3, stamens and pistil 4, sepals and petals.

Characters of the Family.—All members of this family are herbs. Plants belonging to this family are easily recognized by the tetradynamous stamens, the cruciform clawed petals and the peculiar fruit with the false septum (siliqua).

CAPPARIDEÆ.

The Velai (*Gynandropsis pentaphylla*, DC.) plant of this family is an annual herb growing in waste places and it emits a peculiar strong smell.

The plant is erect, and branches well. Leaves are alternate, ex-stipulate, long-stalked, palmately compound ; leaflets are five, sessile ovate-elliptic, acute, entire and hairy on both sides. Inflorescence is a terminal raceme, at first corymbose and afterwards lengthening into a regular elongated raceme.

Flowers have bracts consisting of three sessile leaflets and long viscidly hairy stalks. Sepals are four, free, lanceolate. Petals are also four, white and clawed. There are six stamens that are attached to the gynophore, which carries on its summit the ovary. Fruit is unilocular, with parietal placentation and dehiscent.

This family is well represented in South India and the most common genera occurring in a wild state are Cleome, Capparis and Cadaba. The genus Cleome differs from Gynandropsis in not having a gynophore, but resembles it in other respects. In Capparis we have indefinite stamens and they are not attached to the gynophore. The fruit is a berry and not a dry capsule as in Cleome.

Cleome Chelidonii, L.f., is a weed of clayey soils easily recognized by the rose-coloured flowers. *Cleome viscosa*, L., is another one found everywhere and it is a sticky plant, as its name indicates and bears yellow flowers.

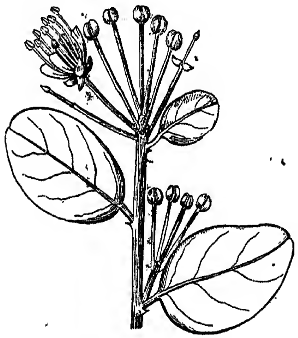


FIG. 344. *Capparis sepiaria*, L.

Capparis sepiaria, L., forms thick impenetrable bushes and flourishes everywhere in the scrubby jungles of South India. There are stipular thorns. The flowers are white, small and in umbels. The fruit alone is borne by the gynophore and it is a berry.

Cadaba indica, L., is another straggling shrub with simple oblong leaves and greenish flowers commonly found in this country. The flower has four stamens borne by the gynophore and the most striking feature of the flower is its tubular disc projecting from the centre of the flower. The fruit is torulose and the seeds are surrounded by a red aril.

FIG. 345. *Cadaba indica*, L.

Characters of the Family.—The plants of this family are herbs, shrubs or trees. Leaves are alternate, with or without stipular thorns, simple or compound. Flowers have four free sepals and petals with definite or indefinite stamens, attached to the gynophore or not. The ovary is one-celled, stalked or not. Fruit is capsular or berried, unilocular with parietal placentation.

VIOLACEÆ.

The very widely occurring weed *Ionidium suffruticosum*, Ging., is a species of this family.

It is a low herb with usually alternate, rarely opposite, linear or lanceolate, coarsely serrate leaves, with fine gland-tipped stipules. Flowers are pinkish or red and solitary. There are five free unequal sepals, not produced below at the base. Petals are unequal, five, four being very small and inconspicuous and one (the lower one) large clawed and saccate at the base. Stamens are five with free filaments and anthers united or free. Two anthers are spurred at the base and all the anthers with their connectives produced beyond the anther-lobes as flaps. The ovary is superior, one-celled, with three parietal placentas. The style is clavate with oblique stigma. The fruit is a somewhat rounded capsule, breaking into three valves. Seeds are rounded, striate and with endosperm.

The commonest species occurring on the hills are *Viola Patrinii*, DC., *V. serpens*, Wall, and *V. distans*, Wall. All the species of this family occurring in South India are herbs

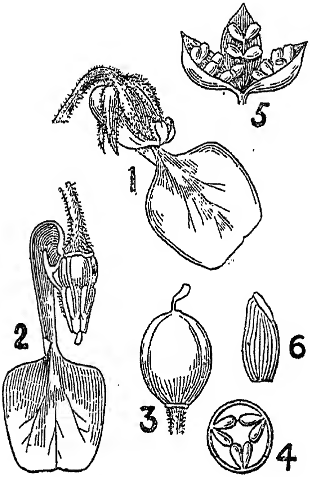


FIG. 346. *Ionidium suffruticosum*, Ging. 1, 2, flowers; 3, ovary; 4, section of the ovary; 5, fruit; 6, seed.

except the one species, *Alsodeia zeylanica*, Thw., which is a tree flourishing on the sides of the low hills of the Western Ghauts.

Plants of this family are mostly herbs or shrubs and rarely trees.

Polygala chinensis, L., *P. erioptera*, DC., *Var Vahliana*, or *P. bolbothrix*, Dunn., may be examined as types.

These are annuals with alternate, simple, ex-stipulate leaves which often vary very much on the same plant. Flowers are yellow in *P. chinensis* and pinkish in *P. erioptera* and *P. bolbothrix*, and they are in racemes, axillary or extra-axillary. There are five unequal sepals, the two inner being larger and somewhat petaloid. Petals are three united at the base only with the staminal sheath, the lower

being boat shaped and crested at the tip. There are eight stamens, with the filaments united into a sheath split on one side. Ovary with a simple curved style, two-celled with a single pendulous ovule in each. Fruit is a loculicidal capsule, two-celled with one seed in each cell. Seeds are hairy with a waxy three-lobed appendage (caruncle) and endosperm.

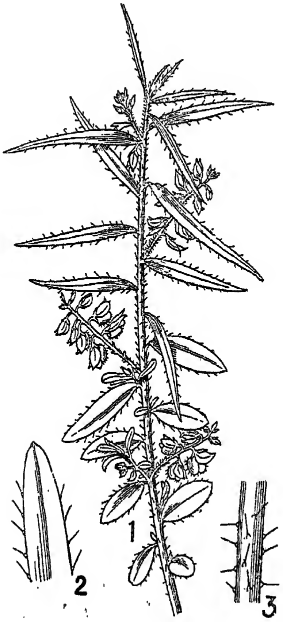


FIG. 347. *Polygala bolbothrix*, Dunn. 1, branch; 2, a part of a leaf; 3, a part of the stem.

There are about a dozen species of Polygala occurring in South India. *Polygala Javanna*, DC., is a pretty species occurring on low hills.

Salomonia oblongifolia, DC., is a very slender small plant mostly confined to the West Coast. *Xanthophyllum flavescens*, Roxb., is a large timber tree belonging to this family found growing on the Nilgiris and in the West Coast.

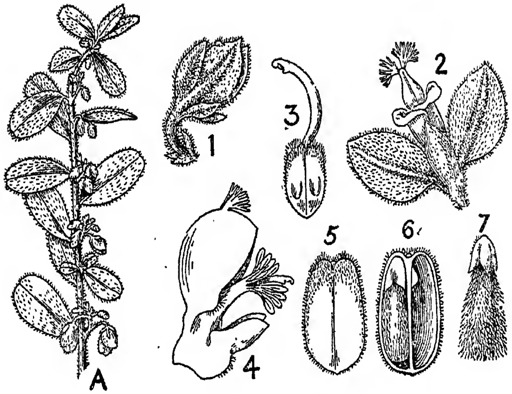


FIG. 348. *Polygala erioptera*, DC., *Var Vahliana.* A. branch; 1, flower-bud; 2, flower; 3, ovary; 4, petals, stamens and pistil; 5, fruits; 6, fruit cut open; 7, seed.

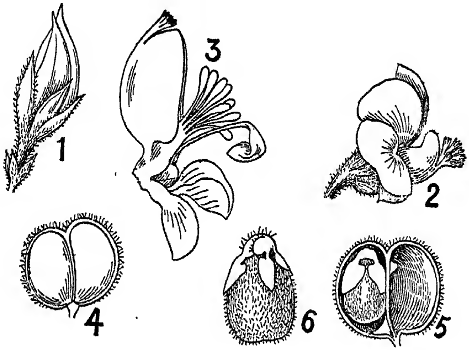


FIG. 349. *Polygala chinensis*, L. 1, flower-bud; 2, flower; 3, petals stamens and pistil; 4, fruit; 5, fruit cut open; 6, seed.

PORTULACACEÆ.

The common weed *Portulaca oleracea*, L., is a species of this family. It is a creeping succulent herb, quite glabrous in all its parts. Leaves are alternate or sub-opposite, cuneate, truncate or rounded at the apex, covered with glistening dots when fresh, sub-sessile and without stipules.

Flowers are clustered towards the ends of branches amidst whorls of leaves, sessile. There are two sepals joined

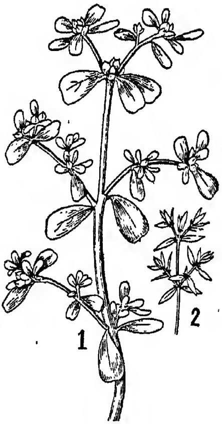


FIG. 350. *Portulaca oleracea*, L. (1) *and P. quadrifida*, L. (2).

below, and the free part deciduous. Petals are obovate, yellow, five. There are eight to twelve stamens. Styles are three- to eight-fid and the ovary is half-inferior and unilocular. The fruit is a capsule opening transversely by means of a lid. Seeds are blackish and with floury endosperm.

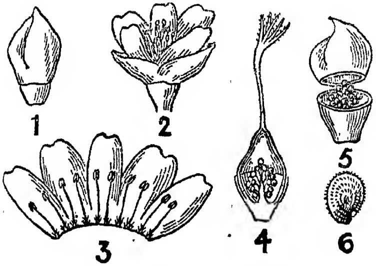


FIG. 351. *Portulaca oleracea*, L. 1, flower-bud; 2, flower; 3, petals and stamens; 4, longitudinal section of the pistil; 5, fruit; 6, seed.

There are five species of Portulaca occurring in South India. *Portulaca quadrifida*, L., is a weed occurring in moist places and it is easily recognized by the ring of silvery hairs at the nodes, the small opposite leaves and the small terminal solitary yellow flowers. Another species *P. wightiana*, Wall, occurs in sandy places and can be recognized by the stipulary scales at the nodes and solitary flowers.

Characters of the Family.—These are all mostly glabrous, succulent herbs. Leaves are entire with or without nodal scales or hairs. Flowers are regular and bisexual. Sepals are two and imbricate. Petals are four or five, fugacious. Stamens are few or indefinite. The ovary is unilocular, free or half-inferior with two- to eight-fid style. Ovules are many at the base or on a central column in the ovary. The fruit is a capsule, dehiscing into valves or circumciss. Seeds are with endosperm.

The common garden Shoe-flower (*Hibiscus Rosa-sinensis*, L.) is a good representative of this family. It is a shrub, branching freely and bearing large showy axillary solitary flowers. Leaves simple, alternate with linear stipules; petiole is short and the blade is ovate with dentate margin.

Flowers are large, the peduncle is jointed, and there are six or more linear bracteoles at the base of the calyx cup which has five triangular teeth. The corolla consists of five large, red, free petals adhering at the base to one another and to the staminal tube, contorted in æstivation. Stamens are monadelphous forming a tube, antheriferous only at the upper half and the anthers are kidney-shaped and one-celled. Ovary is superior, five-celled, with axile placentation; style is very long, slender, branching at the top into five stigmatiferous branches. The ovary does not develop into a fruit in the garden Hibiscus; but in many species of Hibiscus the fruit is a loculicidally dehiscing capsule.

The order is a large one and there are several species that have a wide distribution. The genera Sida, Abutilon, Urena and Pavonia are found everywhere. These genera differ

from Hibiscus in several respects, though they are all alike in all essential characters. In all these genera, the fruit

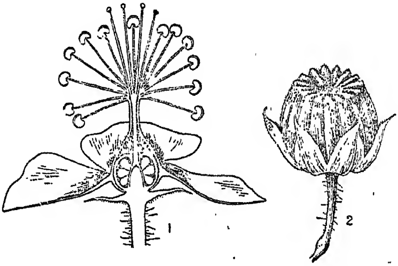


FIG. 352. *Abutilon graveolens*, W. & A. 1, flower cut vertically; 2, fruit.

breaks into its component parts, i.e., it is a schizocarp; bracts are absent in Sida and Abutilon, and there are five bracts in Urena, and Pavonia has five or more. The style branches

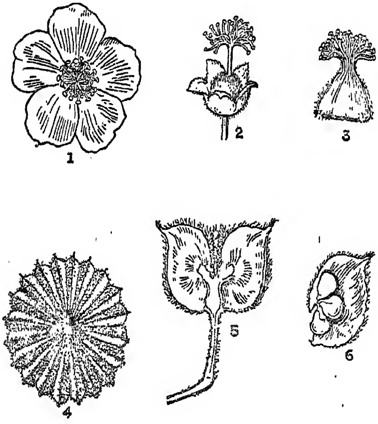


FIG. 353. Floral parts of *Abutilon indicum*, G. Don. 1, front view of flower; 2, pistil; 3, staminal tube; 4, top view of fruit; 5, vertical section of fruit; 6, a segment with seeds.

in Urena and Pavonia are twice as many as the carpels, but in Sida and Abutilon they are as many as the carpels,

Several species of Malvaceæ are under cultivation. The ordinary Cotton plant, *Gossypium herbaceum*, L., *Hibiscus cannabinus*, L., *H. esculentus*, L., and *H. sabdariffa*, L., are all cultivated in South India.

Thespesia populnea, Corr., is a common avenue and seashore tree. Other trees of this order which are of some economic importance are *Eriodendron anfractuosum*, DC., and *Bombax malabaricum*, DC.

The Characters of the Family.—Plants of this order are herbs, shrubs and trees. Leaves are alternate, stipulate, simple, with palmate veins in some cases. Flowers are bisexual, axillary and solitary. Sepals are five, monosepalous. Petals are five, free, contorted and adnate to each other at base and also to the staminal tube. Stamens are united into a tube, indefinite; anthers are reniform, ultimately one-celled. Ovary is three to five or many-celled, with axile placentation. Fruit is either a capsule bursting loculicidally or a schizocarp, with dehiscent or indehiscent cocci. Seeds are reniform, naked or hairy.

STERCULIACEÆ.

This family is represented by eight or nine genera in South India and as types the two species *Melochia corchorifolia*, L., and *Waltheria indica*, L., occurring as weeds all over South India, may be examined.

Melochia corchorifolia, L., is an erect herb with stellately hairy branches. The leaves are simple, alternate, petiolate with small lanceolate stipules. The blade varies from oblong to ovate, serrate, glabrous above and stellately hairy below; base of blade is five-nerved, rounded or cordate.

Flowers are regular, pentamerous in all their parts, densely crowded in axillary or terminal clusters, and with bracteoles. Sepals are free, though slightly connate at base, lanceolate. Petals are pink in colour and longer than the sepals. Stamens are five and united at base into a tube. Ovary is five-celled and two-ovuled.

Fruit is a loculicidally dehiscing capsule; it is globose and enclosed by the persistent calyx. Seeds are black, somewhat angular and in each cavity there is only one seed.

Waltheria indica, L., is somewhat like *Melochia corchorifolia*, L., in habit and in the structure and arrangement of the flower. But the ovary is one-celled and two-ovuled, and the fruit contains only one seed.

Helicteres Isora, L., is fairly abundant in all low jungles in South India and becomes very attractive when in flower, on account of the crimson flowers. The petals are irregular, the stamens are tubular and the ovary has a stalk. The fruit consists of five linear follicles more or less twisted spirally.

Several species of Pterospermum are found in the forests of low hills. The leaves of the trees of this genus vary very much and the fruits are loculicidal woody capsules with winged seeds.

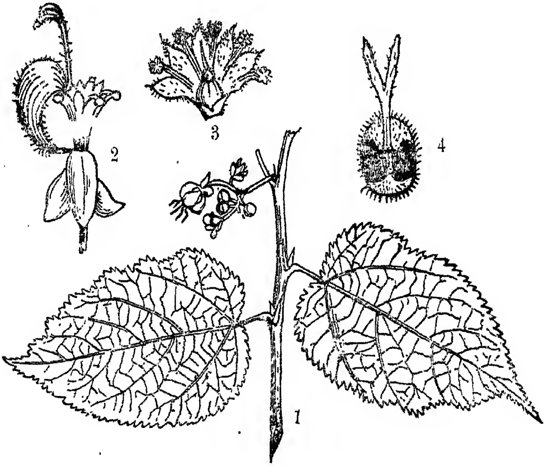


FIG. 354. *Guazuma tomentosa*, Kunth. 1, branch; 2, flower with one petal and andrœceum; 3, stamens and staminodes with pistil; 4, petal.

The tree, *Guazuma tomentosa*, Kunth, is met with in many places as an avenue tree. The petals are concave with two strap-shaped narrow appendages at the apex and there are staminodes. The fruit is also striking in appearance, as it is woody and tubercled, recalling to our mind the mulberry,

Characters of the Family.—The plants of this order are herbs, shrubs and trees. Leaves are alternate, stipulate, simple and shortly petioled. Inflorescence is cymose, axillary. Flowers are regular usually bisexual, though in some species unisexual. Sepals and petals are five and free. Stamens are definite in number, free, with or without staminodes and anthers two-celled. Ovary is five-celled with axile placentation. Fruit is usually a capsule.

The family is a tropical one.

TILIACEÆ.

This order is also a tropical order and five genera occur in South India. The species *Corchorus olitorius*, L., or any other species of Corchorus may be taken as a representative of this order.

Corchorus olitorius, L., is an erect plant sometimes growing to a height of four feet, with a tendency to branch freely. Leaves are alternate, very short stalked, with narrow stipules shorter than the petiole. The blade is ovate to ovate-lanceolate, serrate with the two lowest teeth prolonged downwards as a tail, at base rounded and three to five-nerved.

Flowers are in groups of two or three, axillary with short pedicels. Flower buds are distinctly angled, obovate and tipped with a cusp. There are five sepals and petals, both being free. Stamens are many, free, with two-lobed anthers. Ovary superior, usually five-celled.

Fruit is a cylindrical capsule with ten ribs, five-celled with transverse partitions between the seeds. Seeds are somewhat triangular, dull black.

Triumfetta rhomboidea, Jacq., is another common weed with a wide distribution. This is easily recognised by its small globose fruits, covered with hooks.

The species of Grewia are also very widely spread and they are conspicuous by their cymose inflorescence and drupaceous fruit.

Another genus with many species mostly confined to hills is Elæocarpus. This genus has large flowers with aciniate petals and long linear anthers opening by pores at he apex. The fruit is a one-seeded, one-celled drupe. This

genus is now separated into a family by itself under the name Elæocarpaceæ.

The tree *Berrya Ammonilla*, Roxb., which yields the valuable timber, Trincomali wood, is a member of this family.

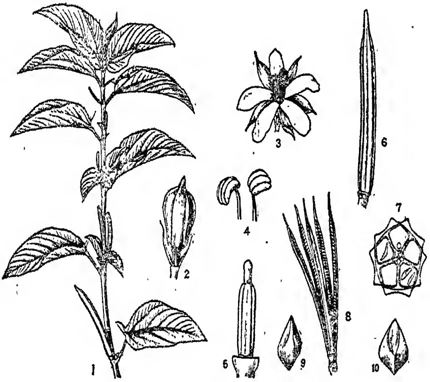


FIG. 355. *Corchorus olitorius*, L. 1, a branch; 2, young flower-bud; 3, flower; 4, stamens; 5, pistil; 6, fruit; 7, transverse section of fruit; 8, capsule burst open; 9 and 10, seeds.

Characters of the Family.—This order includes trees, shrubs and rarely herbs. Leaves are alternate, simple, stipulate. Flowers are regular, bisexual. Sepals and petals are three to five. Stamens are usually indefinite inserted on the edge of the receptacle, and free; anthers two-celled. Ovary is seated on a distinct stalk (torus), two- to ten- celled. Fruit is one- to many- celled, dry or fleshy, dehiscent or indehiscent.

LINACEÆ.

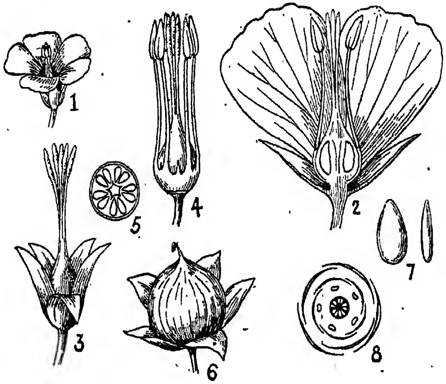
This is a small family with only four genera occurring in South India. The cultivated Flax Plant, *Linum usitatissimum*, L., will serve as a good example of the family.

The Flax Plant is a small annual herb with erect freely branching slender stems. Leaves are small, linear or

lanceolate linear, exstipulate, alternate and entire. The inflorescence is cymose, the main axis terminating in a flower and the succeeding ones behaving similarly so that the inflorescence is scorpioid.

FIG. 356. *Linum usitatissimum*, L.

Flowers are leaf-opposed regular and bisexual. There are five persistent free sepals and five blue fugacious clawed petals. In the bud the sepals are quincuncial and petals contorted. The stamens are five, connate at the base with minute staminodes alternating with the stamens. The ovary is superior, five-celled, though ten-celled due to the formation of false septa, styles are five free. The fruit is a septicidally dehiscing capsule. The seeds are compressed with brownish testa, and scanty endosperm. (See fig. 356.)



357. *Linum usitatissimum*, L. 1, flower; 2, longitudinal section of flower; 3, sepals and gynæceum; 4, stamens and gynæceum; 5. transverse section of ovary; 6, fruit; 7, seeds; 8, floral diagram.

Linum mysorense, Heyne., is a fairly common plant occurring on higher elevations in the hilly regions in South India. It is a slender annual with very small leaves and small yellow flowers. (See fig. 358.)

FIG. 358. *L. mysorense*, Heyne.

Another species of this family occurring widely in the forest on the plains all over South India is *Hugonia Mystax*, L. This plant can easily be recognised by the large yellow flowers, drupaceous fruits and the spiral hooks which are the lowest peduncles. (See fig. 359.)

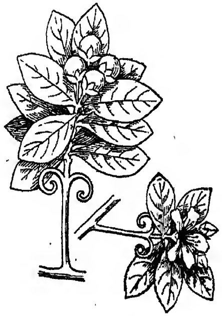


FIG. 359. *Hugonia Mystax*, .

Characters of the Family.—The plants of this family are herbs or undershrubs. Leaves are alternate, simple, usually entire, with or without stipules. Flowers are in cymes, with five free or slightly connate sepals and five fugacious petals. Stamens are five or ten, with staminodes or not, united at the base.

Ovary is superior with three to five free or united styles, three to five celled. Fruit is a capsule or a drupe. Seeds are with endosperm or without it.

This is a small family represented in this part of India by only five genera. The species also are very few except in the genus Impatiens.

The common weed *Oxalis corniculata*, L., is a member of this family. It is a very diffuse annual, with creeping branches bearing long-petioled compound leaves. Leaflets are three and ob-cordate. The inflorescence is an umbel on a slender peduncle.

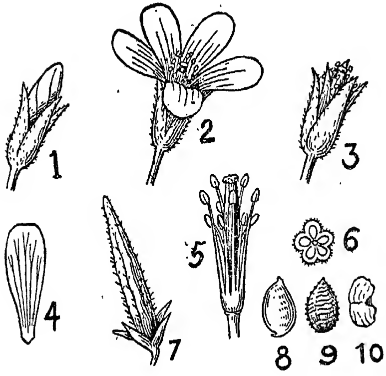


FIG. 360. *Oxalis corniculata*, L. 1, flower-bud; 2, flower; 3, flower without petals; 4, petal; 5, stamens and gynæceum; 6, transverse section of ovary; 7 fruit; 8, seed with aril; 9, seed without aril; 10, aril.

Flowers are regular and yellow. Sepals are free, five and quincuncial. Petals are five, emarginate and contorted. Stamens are ten, five opposite the petals short and five opposite the sepals long. The ovary is five-celled with five free styles. Fruit is a loculicidal capsule. Seeds are usually covered by an outer fleshy aril-like coat bursting elastically and with fleshy endosperm.

Another common weed of this family is *Biophytum sensitivum*, DC. The leaves are usually crowded at the ends of stems and branches, and are pinnately compound and sensitive.

The Genus Impatiens is very rich in species, about 70 species being recorded as occurring in South India. *Impatiens*

FIG. 361. *Impatiens chinensis*, L.

balsamina, L., is a very common plant occurring in wet places in the plains and on low hills. Another common balsam on the hills is *Impatiens chinensis*, L. The most striking feature of balsams is the structure of its flowers. Flowers are irregular with three petaloid sepals, two lateral being small and one large usually produced into a spur. Petals are three, two lateral, called wings and one large one, called

the standard. The stems are very juicy, herbaceous, brittle and transparent. The fruit is a capsule bursting by the mere touch of it, and the name of the genus is derived from this explosive fruit.

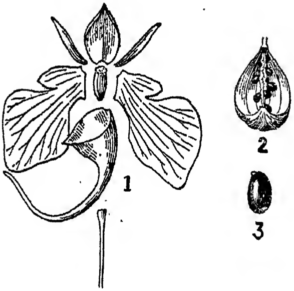


FIG. 362. *Impatiens chinensis*, L. 1, sepals, petals and gynæceum; 2, fruit; 3, seed.

RUTACEÆ.

The common orange, *Citrus aurantium*, L., will serve as an example of this order.

This is a tree with numerous spinescent young branches. Leaves are alternate, exstipulate, compound and unifoliolate with winged petioles. The leaflet is elliptic or oblong elliptic, studded with pellucid oil glands, entire or crenate. Flowers are clustered as small cymes. The calyx is somewhat cup-shaped, usually five-toothed. Petals are usually five, white, linear, oblong thick. Stamens vary in number from ten up to twenty or sometimes even more.

Ovary is eight to many celled. Ovules are many and biseriate and placentation axile; the style is cylindric, prominent with a capitate stigma. Fruit is a many-celled berry with a leathery rind and fleshy hairs within the cavities growing from the inside of the pericarp. Seeds have a coriaceous testa and they are often poly-embryonic.

Other species that may be examined are *Feronia elephantum*, Corr., *Ægle Marmelos*, Corr., *Murraya*

Kœnigii, Spreng., *M. exotica*, L., and *Toddalia asiatica*, Lamk.

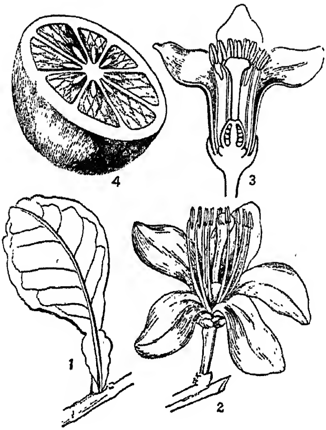


FIG. 363. *Citrus aurantium*, L. 1, leaf; 2, flower; 3, longitudinal section of flower; 4, fruit cut across.

Feronia elephantum, Corr., is a spinous tree with compound leaves. Flowers are unisexual, dull red and in panicles, both male and female flowers are found in the same panicle. The fruit is a berry with a woody rind. Seeds are immersed in pulp.

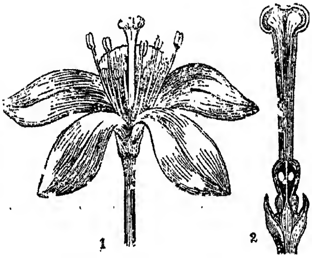


FIG. 364. *Murraya exotica*, L. 1, flower; 2, pistil.

Toddalia asiatica, Lamk., is a very prickly shrub and it forms an impenetrable thicket on the plains, but on the hills it grows larger.

Characters of the Family.—Many of the members of this family are tropical in distribution and consist of trees, shrubs

and herbs and all parts abound in oil glands, though these are more prominently seen in leaves as translucent glands. Leaves are simple or compound, alternate and without stipules. Flowers are bisexual usually with four or five petals and a cupular calyx with the same number of teeth. Stamens vary in number from five to ten or more. There is a distinct disc inside the stamens. Ovary is four to many celled, style stout and stigma capitate. Fruit is usually a berry.

MELIACEÆ.

This is another family whose members are widely distributed in the warm regions of the Old and the New World. The common Margosa or Nim tree is a good representative of this family.

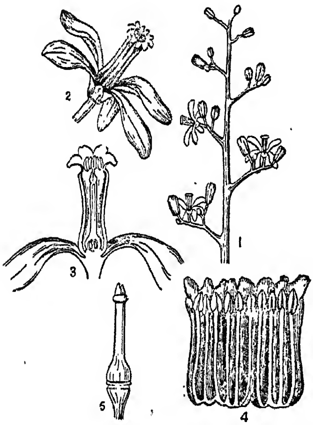


FIG. 365. *Azadirachta indica*, A. Juss., 1 inflorescence; 2, flower; 3, longitudinal section of a flower; 4, staminal tube laid open; 5, pistil.

Azadirachta indica, A. Juss., is a large tree with a straight trunk. Leaves are found crowded towards the ends of the branches. They are alternate, exstipulate, compound, odd pinnate. Leaflets are obliquely lanceolate or falcate, toothed, sub-opposite and vary in number from nine to thirteen.

Flowers are regular, hermaphrodite and in narrow axillary panicles. Calyx is finely hairy and deeply five-lobed. Petals are five narrowly obovate oblong or spathulate, ciliate. Stamens form a tube narrow at base and somewhat broad at the top with recurved teeth, anthers are ten and opposite the teeth. Ovary is three-celled, style is longer than the ovary and the stigma is three-toothed.

Fruit is a drupe. Seed without endosperm, ellipsoidal, single with very thick cotyledons.

Other members usually met with in the forests of South India are *Cipadessa baccifera*, Miq., *Amoora Rohituka*, W. & A., *Walsura piscidia*, Roxb., and *Heynea trijuga*, Roxb. Some species of this order yield well-known timbers. *Chukrasia tabularis*, A. Juss., yields the "Chittagong wood" or the white "cedar." The well-known "satin wood" is the timber of *Chloroxylon Swietenia*, DC. *Cedrela Toona*, Roxb., is another valuable timber tree known by the name Toon or the Indian Mahogany.

Amoora Rohituka, W. & A., has large capsular fruits with seeds each of which is immersed in a very conspicuous scarlet aril.

Characters of the Family.—The order includes shrubs and trees. Leaves are alternate, exstipulate and compound. Flowers are regular, hermaphrodite and in axillary or terminal panicles. Calyx is four- or five-lobed. Petals are four or five, usually free, imbricate or valvate. Stamens are five or ten; filaments united into a tube; anthers are introrse. Disc is present or absent. Ovary is two- to five-celled; style is simple with a capitate stigma. Fruit is a capsule, a berry or a drupe. Seeds are winged or not.

√ RHAMNEÆ.

The tree *Zizyphus Jujuba*, Lamk., is a good type of the family. It is a small tree widely distributed in this country.

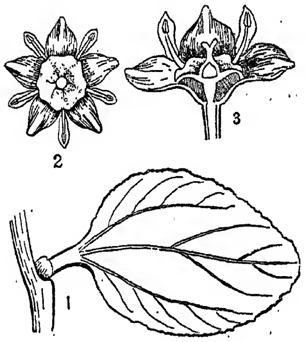


FIG. 366. *Zizyphus Jujuba*, Lamk. 1, leaf; 2, flower; 3, flower, cut vertically.

The tree is generally small but branching very much. Leaves are alternate with stipular shortly stalked and simple; the blade is ovate-elliptic, unequal at base, three-nerved, finely dentate, green above and densely hairy below.

Flowers are in axillary cymes, small and

greenish yellow. The calyx consists of five, free, triangular sepals, woolly outside, valvate in bud, keeled on the inner face and petals are five, concave, very small. Stamens are five, opposite the petals. Ovary is immersed in a distinct disc, two-celled ; style two-branched.

The fruit is globose and drupaceous, one- or two-seeded.

The other species of Zizyphus usually met with in South India are *Z. Œnoplia*, Mill., *Z. rugosa*, Lamk., and *Z. xylopyrus*, Willd.

Scutia indica, Brongn., a straggling shrub occurring as bushes in all scrub jungles is a member of this family. The branches are armed with recurved prickles.

Ventilago madraspatana, Gærtn., is another scandent shrub widely distributed; it is easily recognized by the shining leaves with peculiar parallel close-set venation and by its winged fruits.

Characters of the Family.—The species of this family are trees or shrubs, erect or scandent. Leaves are alternate stipules small or spinescent. Flowers are regular, bisexual, small, greenish and in cymes. Calyx has four or five triangular, keeled sepals that are valvate in bud. Petals are four or five, inserted on the throat of the calyx tube, small, concave. Stamens are four or five opposite the petals and embraced by them, and are inserted outside the disc anthers versatile. Disc is the calyx tube, entire or lobed. Ovary is three-celled, immersed in the disc ; style erect two- to four-fid.

Fruit is either a drupe or it is winged. Seeds have endosperm.

Most of the species are of the warm regions of the world.

This family is represented in South India by the genera Vitis, Tetrastigma, Ampelocissus, Parthenocissus, Cissus, Cayratia and Leea.

Of the many species of Cissus commonly met with in this country, *Cissus quadrangularis*, L., may be examined as a type.

Cissus quadrangularis, L., is a well-known quite common climber, conspicuous by its fleshy, square, slightly winged stems with deep constrictions and simple tendrils at

the nodes. The axis though straight is a sympode. Leaves are alternate with petioles and somewhat ovate conspicuous small stipules ; the blade is ovate, sometimes lobed, cordate or rounded or cuneate at base. Flowers are in cymes that are open and loose and the inflorescences are usually opposite the leaf. Flowers are regular, small or whitish, bisexual and tetramerous. Calyx is small, four-toothed. Petals are four, hooded. Stamens are opposite the petals. Disc is distinct, four-lobed. Ovary is two-celled, with two ovules in each cell. The fruit is an ovoid berry, red when ripe.

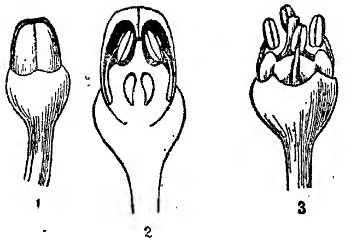


FIG. 367. *Cissus quadrangularis*, L. 1, flower-bud ; 2, flower-bud, longitudinal section ; 3, flower, without the petals.

The species of Leea can easily be recognized by their erect shrubby habit, compound leaves and large sheathing stipules.

Characters of the Family.—The members of the family are shrubs, mostly climbing by means of tendrils. Leaves are alternate, stipulate, simple or compound. Inflorescence is cymose. Flowers are regular and bisexual. Calyx is four- or five-lobed, cup-shaped. Petals are four or five, concave, valvate in bud, caducous. Stamens are four or five, free or united ; but the filaments are opposite to the petals. Disc is large, annular. Ovary is two-celled in Vitis and the other genera mentioned above and six-celled in Leea. Fruit is a berry. Seeds have endosperm.

The common balloon-vine, *Cardiospermum Halicacabum*, L., is a member of this family. It is a tendril climber with very wiry stems. Leaves are alternate, exstipulate, twice compound, with long petioles ; leaflets are lanceolate, coarsely toothed, slightly hairy or glabrous and have acute tips.

Flowers are small, irregular, polygamous and are arranged in umbellate cymes ; the flower stalks are slender but the

peduncle is stiff and erect, with two tendrils just below the flowers. The calyx consists of four free sepals, the two outer being smaller and the two inner larger and thin. There are four petals, two large with scales and two small and lower with small crested scales; just opposite the small petals there are two glands representing the disc. Stamens are eight, eccentric with hairy unequal filaments. The ovary is globose, three-celled with a single ovule in each.

Fruit is a three-valved inflated capsule; it is pyriform and compressed from top, and slightly winged at the corners. Seeds are black with a white heart-shaped mark or aril (hence the generic name Cardiospermum).

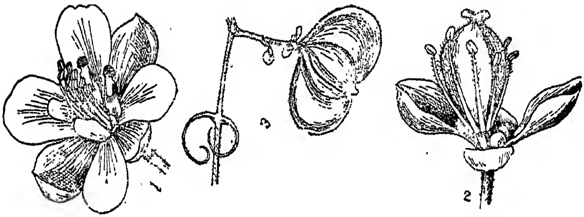


FIG. 368. *Cardiospermum Halicacabum*, L. 1, male flower; 2, bisexual flower; 3, fruit. Note the scales in 1 and the glands in 2.

Another common species *Cardiospermum canescens*, Wall., may also be examined. It differs from *C. Halicacabum*, L., by having larger flowers, larger rounded capsules.

Allophylus serratus, Radlk., is a shrub very commonly met with in low forests and even in scrubby jungles. It is easily recognised by the three-foliolate leaves crowding at the extremities of branches, and the axillary racemes of small flowers, replaced later by small red berries.

Sapindus emarginatus, Vahl., is the Soapnut tree. It is a large tree with compound leaves having four to six oblong emarginate leaflets and with large panicles of flowers. The fruit consists of three distinct fleshy lobes, each separating with a single large black seed.

Dodonæa viscosa, L., is a low shrub with diœcious or polygamous flowers found in dry places, all over the plains.

It grows almost into a tree on high hills. The plant is easily recognised by the crowded, lanceolate, shining leaves and the winged capsules.

Characters of the Family.—Except the species of Cardiospermum, all the other members of this order are either shrubs, or trees. The leaves are mostly exstipulate, and usually compound. The flowers are generally small, regular or irregular, polygamous or diœcious. There are four or five sepals that are valvate or imbricate in bud. We have the same number of distinct petals, that are unequal and sometimes with scales as outgrowths. There is a disc which varies in its character. Of stamens there are usually eight, but in some species it may vary from five to ten. The insertion of stamens may be inside the disc or unilateral. The ovary is two- or three-celled, one- or two-ovuled. The fruit is indehiscent and fleshy or capsular. Seeds are arillate or not, but without endosperm.

The members of this family abound in the tropics and are most abundant in America.

ANACARDIACEÆ.

The mango tree, *Mangifera indica*, L., may be examined as a type of this family. It is a tree with a tendency to grow tall and large, containing an acrid juice in its branches and fruit. Leaves are glabrous and shining, and are crowded together at the ends of branches. There are found at the extremities of branches terminal scaly buds from which emerge young leaves, which are reddish in colour but becoming green later. Leaves are simple, exstipulate, alternate and the petioles are short; the blade varies in shape from oblong to oblong lanceolate or lanceolate; the margin is entire, but sometimes wavy.

Flowers are small polygamous and in terminal panicles. Sepals are five, somewhat shorter than the petals, concave and ovate. There are five oblong petals with three ridges on the inner face and the margins reflexed. Disc is prominent fleshy and five-lobed. There is a single perfect stamen inserted within the disc, the others being small and imperfect; the anther is purple. Ovary is one-celled and one-seeded with a lateral style,

Fruit is a drupe, varying in size according to the varieties. Seed, single, large with massive cotyledons.

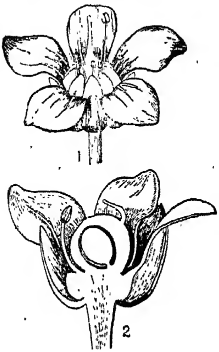


FIG. 369. *Mangifera indica*, L. 1, flower; 2, vertical section of flower.

The family is not a very large one and in India the following species are fairly common.

The two trees *Buchanania angustifolia*, Roxb., and *B. latifolia*, Roxb., are fairly common in the forests and scrubby jungles. They are easily recognised by their having their panicles shorter than the leaves. Further, the flowers are hermaphrodite and possess eight stamens. The drupes are small.

The deciduous tree *Odina Wodier*, Roxb., is a well-known one. It can be recognised with ease by its smooth bark and by the branches bearing unisexual flowers in spikes, at a time when they are bare of leaves. Leaves are pinnately compound.

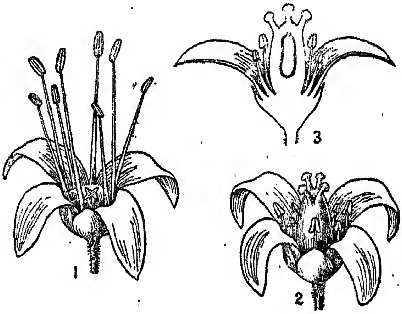


FIG. 370. *Odina Wodier*, Roxb. 1, male flower; 2, female flower; 3, female flower, longitudinal section.

The Cashew-nut tree (*Anacardium occidentale*, L.) is widely spread. This tree has a very crooked trunk and the

branches are low lying in sandy tracts. Leaves are large rounded at the apex. Flowers are in terminal panicles and the pedicels of flowers grow and become fleshy and massive bearing the fruit at its end.

Characters of the Family.—Most of the members of this family are trees with acrid juice. Leaves are alternate and exstipulate. Flowers are small, regular, polygamous, unisexual or bisexual and are in panicles. Sepals and petals are free and four to five in number. Stamens are same in number as the petals, or twice and are inserted inside a conspicuous disc. Ovary is superior, one-celled and one-ovuled. Fruit is a drupe. Seeds are large and without endosperm.

This family being a large one it is necessary to select as types three or four plants.

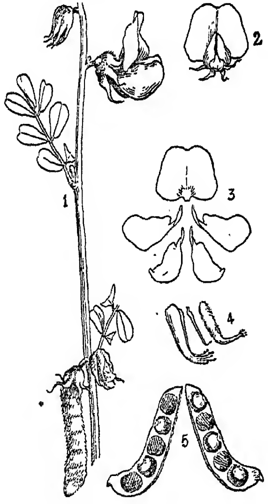


FIG. 371. *Tephrosia hirta*, Ham. 1, floral branch ; 2, flower; 3, petals; 4, stamens and the pistil; 5, fruit and seed.

The plant *Crotalaria verrucosa*, L., is a copiously branching shrub with quadrangular stems. Leaves are alternate, simple with well developed, green, semilunar stipules; the blade is large, broadly ovate, with entire but wavy margins and prominent veins. Flowers are large and are in racemes that are leaf-opposed. The bract is narrow, acuminate and shorter than the pedicel. The calyx is finely hairy outside with five triangular, acuminate teeth. The corolla is papilionaceous, and blue in colour ; standard is somewhat orbicular in shape : the wings are shorter than the standard and the keel-petals which are equal to the wings in length are

completely united and are prolonged into a sharp curved beak. The stamens are ten, monadelphous with dimorphous anthers. Ovary is monocarpellary, one-celled and many-ovuled; style is long with a minute stigma.

Fruit is a turgid, straight, sessile legume with ten or twelve seeds.

Other species of Crotalaria that are of common occurrence are *C. retusa*, L., *C. biflora*, L., *C. juncea*, L., and *C. medicaginea*, Lamk.

Tephrosia purpurea, Pers., and *T. hirta*, Ham. are found everywhere in South India. The flowers are in racemes and the corolla is papilionaceous and pink in colour. Stamens are diadelphous and the legume is flat and curved.

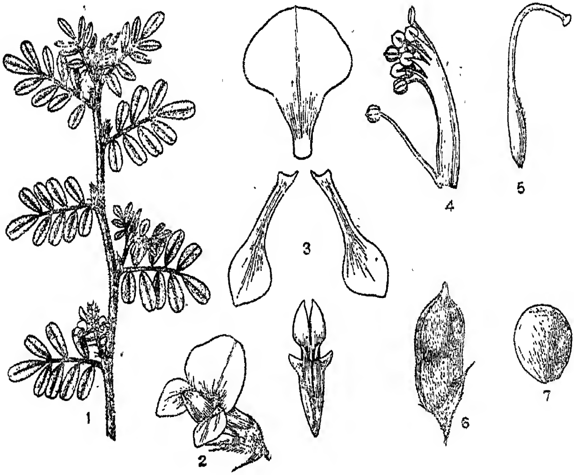


FIG. 372. *Indigofera enneaphylla*, L. 1, branch; 2, flower; 3, petals; 4, stamens; 5, pistil; 6, fruit; 7, seed.

Several species of Indigofera besides the cultivated indigo plant are met with. *Indigofera enneaphylla*, L., is a prostrate herb found in all waste places and amidst pastures. It has small compound leaves and small bright, deep pink flowers. *I. trita*, L., is an erect plant frequently met with in all situations.

The genus Indigofera is easily recognised by the hairs that are fixed by the centre, the keel-petals spurred on both sides, and the diadelphous stamens.

The species of Leguminosæ that have a papilionaceous corolla form a distinct sub-order Papilionaceæ. There are many genera and species of this sub-order growing in South India in a wild state. The following are a few of them: *Sesbania ægyptiaca*, Pers., *Abrus precatorius*, L., *Teramnus labialis*, Spreng., *Clitoria Ternatea*, L., *Rhynchosia minima*, DC., *Desmodium triflorum*, DC., *D. biarticulatum*, Benth., *Pongamia glabra*, Vent., *Zornia diphylla*, Pers., and *Alysicarpus monilifer*, DC. Besides these many species such as, *Sesbania grandiflora*, Pers., *Dolichos Lablab*, L., *Canavalia ensiformis*, DC., *Phaseolus Mungo*, L., *Vigna Catiang*, Endl., *Cicer arietinum*, L., *Cajanus indicus*, Spreng., and several others are under cultivation.

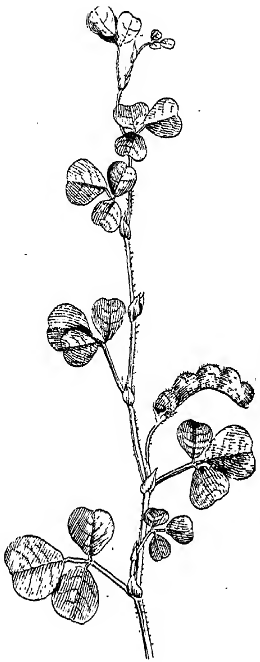


FIG. 373. *Desmodium triflorum*, DC.

Cassia auriculata, L., or *Cassia siamea*, Lam., may be examined as a type of the next sub-order Cæsalpineæ. The former is a shrub and the latter a tree. The leaves are compound in both and the leaflets are oblong. The stipules are large and semilunar in *C. auriculata* and they are small and caducous in *C. siamea*. Flowers are in racemes, and corymbose, but simple in the first and compound in the second. The calyx consists of five, free, petaloid sepals unequal, concave and quincuncially imbricate. There are five yellow petals with long claws, and they are

imbricate in bud with the upper petal innermost. Stamens are ten, some only perfect, and three being barren; anthers

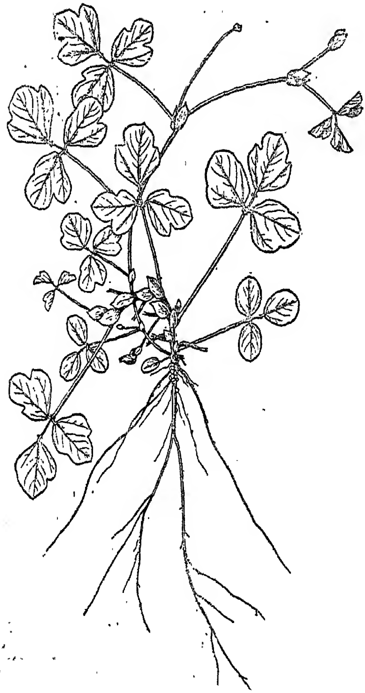


Fig. 374. *Phaseolus trilobus*, Ait.

open by apical pores. The ovary is monocarpellary and one-celled with many ovules.

Fruit is a thin flat legume dehiscing by both sutures. Seeds without endosperm.

Cassia Fistula, L., is a tree very conspicuous in the hot weather on account of the abundant drooping racemes of bright yellow flowers and long black cylindrical fruits.

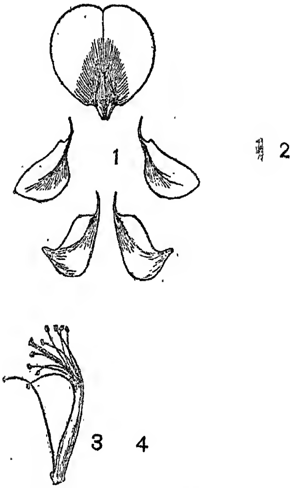


FIG. 375. *Vigna Catiang*, Endl. 1, Petals; 2, fruit; 3, stamens; 4, calyx; 5, pistil

The garden plant *Cæsalpinia pulcherrima*, L. (the Peacock flower) belongs to this sub-order. It is a low, very

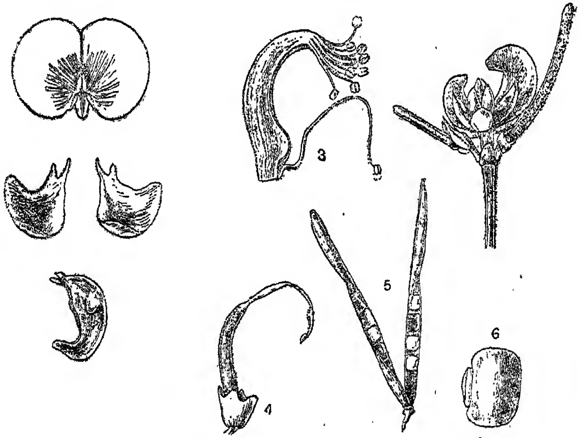


FIG. 376. *Phaseolus Mungo*, L. 1, Inflorescence; 2, petals; 3, stamens; 4, calyx and pistil; 5, fruit; 6, seed.

much branching tree with large terminal racemes of yellow or red flowers. The petals and sepals are very much as in Cassia, but the claws of the petals are more marked and all the ten stamens are fertile. The filaments are fine and very long, sometimes hairy at the base.

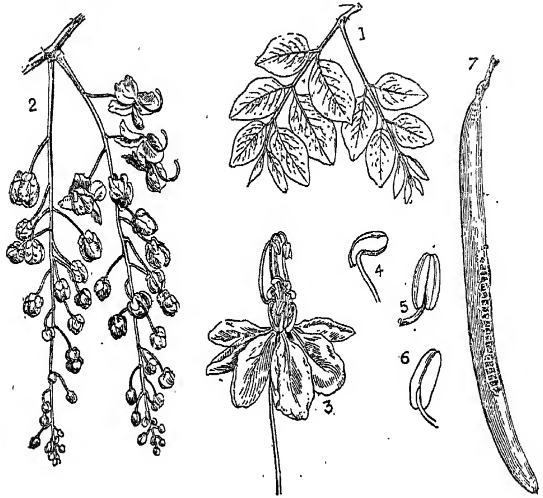


FIG. 377. *Cassia Fistula*, L. 1, leaves; 2, inflorescence; 3, flower; 4, 5, 6, stamens; 7, fruit.

The tamarind tree, *Tamarindus indica*, L., is another example of this order. It is a large tree with compound leaves whose leaflets are sensitive to a certain extent to light. The flowers are in racemes, and they have both bracts and bracteoles. The calyx is somewhat elongated at the base in the form of a tube and has four segments only. There are only three petals with red veins, and three stamens. The fruit is a legume with a fleshy mesocarp.

The genus Bauhinia is easily recognised by the two-lobed or cleft leaves and by the spathaceous calyx.

As examples for the sub-order Mimoseæ the Babul, *Acacia arabica*, Willd., or any other species of Acacia may be examined.

The Babul or *Acacia arabica*, Willd., is a small tree with numerous branches bearing stipular spines. Leaves are alternate, stipulate, with glands on the rachis, bipinnate;

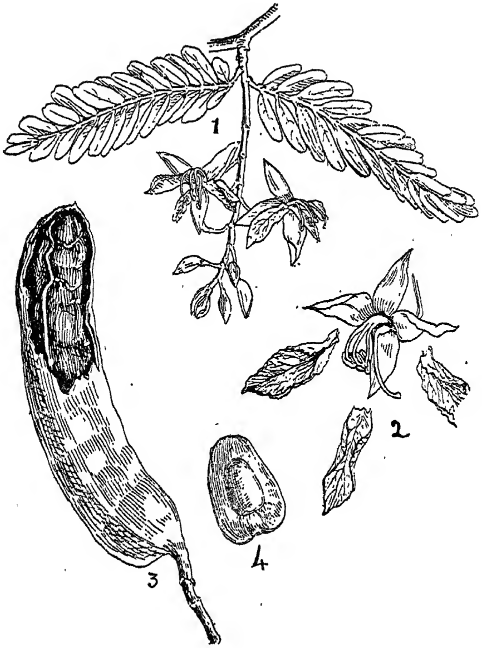


FIG. 378. *Tamarindus indica*, L. 1, branch; 2, floral parts; 3, fruit; 4, seed.

leaflets are small. (See fig. 171.) Flowers are grouped in heads that are fascicled in the axils of leaves. There are two bracteoles. The calyx is bell-shaped with five very short teeth. Corolla is tubular, yellow with triangular lobes. Stamens are indefinite, very much exserted. Ovary is one-celled with many ovules.

Fruit is a stalked, compressed legume covered with soft white hairs and indented on both sides between the seeds and hence moniliform.

Acacia leucophlaea, Willd., differs from the Babul in having white flowers and pods not constricted. The yellow flower heads of *A. Farnesiana*, Willd., are very fragrant, but the turgid cylindrical legumes have an offensive smell. *Acacia concinna* DC., is a huge climber whose fruits are largely used as soap. The very much branched shrub *Dichrostachys cinerea*, W. & A., with its very pretty spikes of red and yellow flowers forms a special feature in some scrubby jungles. Another tall tree, quite conspicuous by its flat broad and thin fruits and white globose flower heads, is *Albizzia Lebbek*. The plant largely used for hedges, *Pithecolobium dulce*, Benth., possesses legumes circinately twisted and seeds with massive arils.

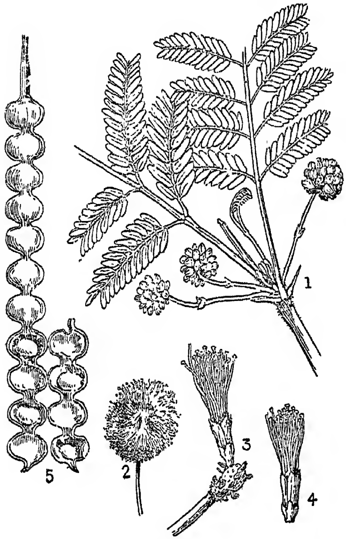


FIG 379. *Acacia arabica*, Willd. 1, branch; 2, flower head; 3, 4, flowers; 5, fruit.

Characters of the Family.—The members of this order are extremely varied in their habit. They are herbs, shrubs, climbers and trees. Leaves are simple or compound, alternate, usually stipulate. Flowers, regular or irregular and bisexual. Sepals

FIG. 380. *Pithecolobium dulce*, Benth. 1, branch; 2, 3, flower-head; 4, flower.

are five, free or united. Petals are five, free. Stamens are ten or indefinite, free or united in various ways. Ovary is monocarpellary, one-celled and many-ovuled. Fruit is a legume.

S. order (1)—*Papilionaceæ.*—Flowers, papilionaceous, the standard being the outermost in the flower bud. The stamens are either monadelphous or diadelphous.

S. order (2)—*Cæsalpineæ.*—Flowers are regular but the petals are usually clawed and the uppermost one is the innermost in the flower bud. Stamens are ten, all or only a few fertile and are much exserted; filaments are always free.

S. order (3)—*Mimoseæ.*—Flowers are usually small, collected together in heads or spikes, bisexual, but also with male and barren flowers in the same head or spike in some genera. Sepals and petals are valvate in bud. Stamens are definite or indefinite, exserted and free.

The most marked feature of this order is undoubtedly the fruit, which is a legume in most cases. But there is a large amount of variation in the structure of the fruit. We have dehiscent, as well as indehiscent dry fruits; the pericarp is also pulpy in some cases and in others the fruit becomes very turgid and cylindrical; there are also winged fruits that are really samaras. In spite of all these variations, they are all monocarpellary.

This family besides being the second largest order containing over 6,000 species, comprises more useful plants than any other order, except probably Gramineæ.

√ COMBRETACEÆ.

The tree *Terminalia Arjuna*, W. & A., is a good example of this family. This is a large tree with smooth greenish white bark, peeling off in large pieces. Leaves are alternate and subopposite, simple and exstipulate, oblong to elliptic oblong, with short petioles. There are also two glands at the base of the leaf close to the petiole, one on each side.

Flowers are in spikes, with short bracteoles. The calyx is campanulate with five triangular teeth. Petals are absent. Stamens are ten and inserted on the disk clothed with hairs. Ovary inferior, one-celled with two or three pendulous ovules

Fruit is a fibrous-woody drupe with five hard projecting wings. Seed single and without endosperm.

Instead of this species, *Terminalia Catappa*, L., and *T. C* may scandent shrub found everywhere on the West Coast and it is easily recognised by its small ellipsoidal crowned by the persistent calyx. When the stem is cut during hot weather large quantities of water flow from the cut ends.

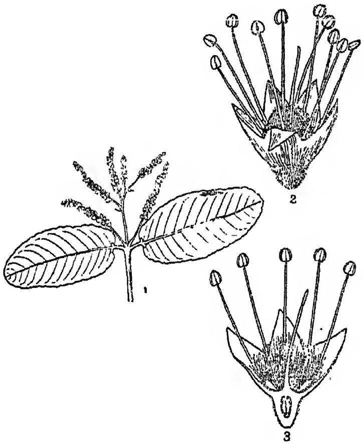


FIG. 381. *Terminalia Arjuna*, W. & A. 1, flower bearing branch; 2, flower; 3, longitudinal section of a flower.

Gyrocarpus Jacquini, Roxb. (*G. americanus*, Jacq.) is a deciduous tree and is very conspicuous during the hot weather on account of the fruits with two large wings (Calyx segments). (See fig. 309.)

Characters of the Family.—This order is a very well defined one with only a few species. They are either trees, or scandent or erect shrubs. Leaves are alternate or opposite, simple, exstipulate and the petioles often bearing glands at the top. Flowers are in spikes and are small without petals. Calyx four to five fid. Stamens are free, equal or double the calyx lobes. Ovary is inferior, one-celled with two or more pendulous ovules. Fruit is usually dry and indehiscent, in some drupaceous and winged. Seed single, without endosperm, cotyledons convolute.

MYRTACEÆ.

The evergreen tree *Syzygium Jambolanum*, DC., is a suitable type for this order. It is a large tree with coriaceous

shining leaves that are opposite, exstipulate, gland dotted and petioled. The leaf blade is elliptic or oblong with an intra-marginal vein. Flowers are small in panicled cymes, usually fragrant and white. The calyx is short with four lobes. Petals are four, falling away in one piece, though free. Stamens are indefinite and the filaments are all folded inwards in the bud; anthers are versatile. The ovary is or, two-ce with many ovules in each cell. Fruit is a dark purple ellipsoidal or globose berry, with a single seed.

The Guava tree (*Psidium Guyava*, L.) may be selected as a type if species of Syzygium are not available. The leaves of this plant are opposite, oblong with very prominent veins. Flowers are large, solitary or in simple cymes. Fruit is an inferior berry with persistent calyx lobes at the top.

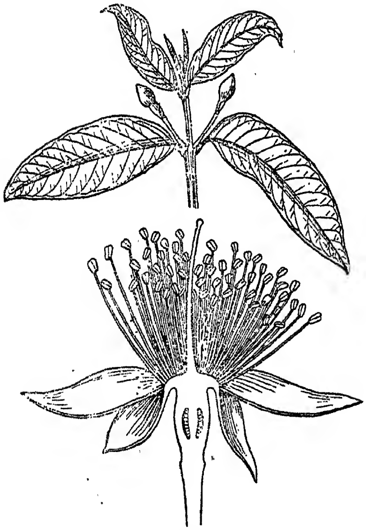


FIG. 382. *Psidium Guyava*, L.

Many species of Syzygium are met with in the forests of South India. One of the commonest trees found scattered, here and there in the forests both on the East Coast and West Coast is *Careya arborea*, Roxb. It is a very striking one on account of its large obovate leaves collected at the ends of branches, large flowers and big green berries.

Characters of the Family.—The members of this family are mostly trees though there are one or two shrubby species

The leaves are opposite, simple, exstipulate, entire, gland dotted with an intra-marginal nerve. Flowers are regular bisexual, solitary, in cymes, or cymose panicles. The calyx is superior, with four or five teeth. Petals are four or five, free, inserted at the margin of the disk, falling away in one piece. Stamens are numerous, filaments long and conspicuously coloured and folded down in the bud. Ovary is inferior, two-celled with one or many ovules.

Fruit is a berry with the calyx limb on its top, one-celled, one-seeded or with many seeds imbedded in pulp.

CUCURBITACEÆ.

The pretty common creeper of the hedges, *Coccinea indica*, W. & A., is a good example of this order. The plant climbs by means of simple tendrils and the stem is thin and grooved. The leaves are alternate, exstipulate, simple and petiolate ; the blade is palmately five-lobed and the depth of lobing varies very much from being very deep to mere angles, and there are five veins at the cordate base, sometimes with glands between the nerves. Flowers are diœcious. Both male and female flowers are axillary and solitary. The calyx is narrow, bell-shaped and has five long teeth, and the corolla is campanulate, white and five-lobed. The corolla and the calyx are similar in both the kinds of flowers. Stamens are three with the filaments forming a column. The anthers of two stamens are complete but that of one is half and they are all united. The anther lobes are long and sinuously folded. The ovary is inferior, narrowly fusiform, glabrous, one-celled with three parietal placentas, ovules many. There are three bifid stigmas.

The fruit is a berry, ellipsoidal or oblong with white stripes or not, beautiful scarlet in colour when fully ripe. Seeds are obovoid.

Any of the cultivated species of the genus Cucurbita may also be examined. These are all large climbers with hairy stems and large leaves, and the tendrils are usually three or four-fid. Flowers are very large, yellow and monœcious. The calyx, corolla and the stamens are all like those of Cephalandra, but are larger. Fruit is a large berry with parietal placentas (Pepo).

Many of the members of this family are cultivated. All the Gourds, Cucumbers and Melons belong to this family. The plants, *Cucumis pubescens*, Willd., and *C. trigonus*, Roxb., occur in a wild state and they differ from Coccinea and Cucurbita in having their connectives produced beyond the anther lobes forming a kind of crest. *Trichosanthes anguina*, L., or the Snake gourd has fimbriate petals and the Bitter gourd, *Momordica Charantia*, L., is easily recognised by its

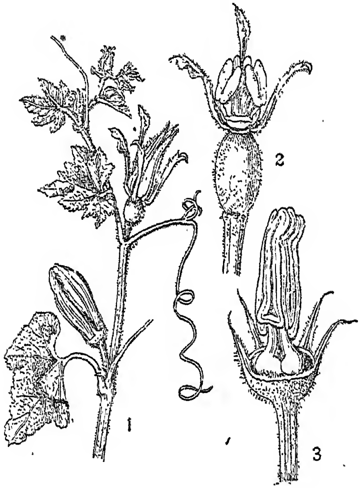


FIG. 383. *Cucurbita moschata*, Duch. 1, branch; 2, female and 3, male flower.

fleshy tubercled fruits. *Citrullus Colocynthis*, Schrad., is found in all waste places and is conspicuous by its palmately deeply lobed leaves and by the intensely bitter globose fruits with white streaks. *Blastania Garcini*, Cogn., with its pretty tiny scarlet fruits, and large stipule-like bracts and *Melothria maderaspatana*, Cogn., with its round bright red berries are occasionally met with, all over South India.

Characters of the Family.—This is a very well defined order, consisting mostly of climbers with hollow stems and simple or branched tendrils. Leaves are simple, alternate,

exstipulate, cordate at base, entire or palmately lobed and with coarse hairs. Flowers yellow or white, monœcious or diœcious, solitary or racemed. The calyx tube is adnate to the ovary and so the calyx lobes are superior. The sepals and petals are five in number. Petals are united, rarely free.

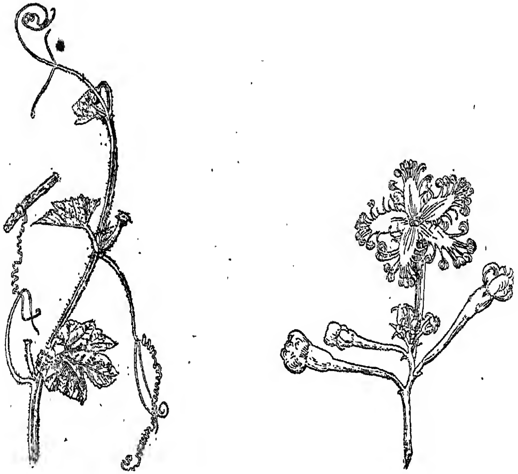


FIG. 384. *Trichosanthes anguina*, L. The left hand figure is a branch with female flowers and the right hand one is an inflorescence of male flowers.

Stamens are three attached to the calyx tube; anthers free or cohering, lobes conduplicate or flexuose, and the connective produced beyond the apex of the anther or not. Ovary is inferior, three carpellary, but one or three-celled with three parietal placentas. Fruit is a berry with a hard rind. Seeds many and usually flat.

AIZOACEÆ.

This is a small order represented by a few genera. The most troublesome weeds *Trianthema Portulacastrum*, L., and *T. decandra*, L., are plants of this order. Both are herbs with prostrate branches springing from a stout root. The leaves are petiolate, opposite, unequal and entire; in the

former it is round or obovate with petioles somewhat dilated and membranous at the base and that of the smaller leaf forms a pouch in which the flowers are situated; in the latter the leaves are elliptic-oblong and the petioles are dilated and amplexicaul at base, but do not form pouches enclosing flowers and fruits.

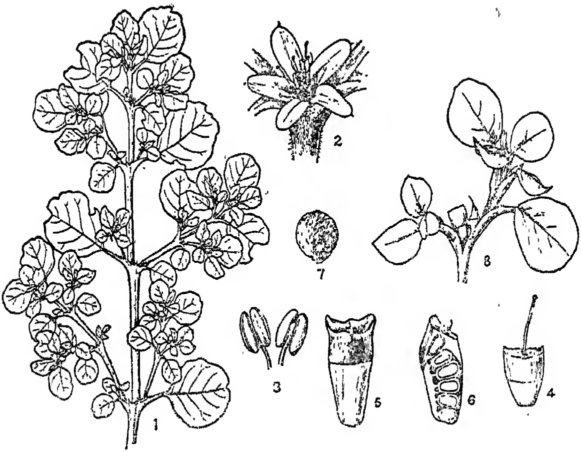


FIG. 385. *Trianthema Portulacastrum*, L. 1, branch; 2, flower; 3, stamens; 4, pistil; 5, fruit; 6, vertical section of fruit; 7, seed; 8, leaf pouch opened to show the position of fruit.

Flowers are solitary, sessile and within the petiolar pouch in *T. Portulacastrum*, but they are in axillary dichasiums in *T. decandra*. Calyx consists of five deep lobes bearing a short process at the apex and coloured light pink within. Petals are not present. There are ten to twenty stamens in *T. Portulacastrum* and ten stamens only in *T. decandra*. Ovary is free, superior, sessile and truncate. Style is single in *T. Portulacastrum* and two in *T. decandra*. Fruit is a capsule, membranous below, and hardened into a cap above, which gets detached by circumcissile dehiscence. Seeds are three to five, black, reniform or orbicular, striate or muricated.

Trianthema triquetra, Rottl., is also fairly common in open waste places. It is a small much branched herb, with prostrate branches and woody root-stock.

Many species of Mollugo are also met with as weeds everywhere. *Mollugo lotoides*, O. Kze., is extremely common in clayey soil and tank beds, and this plant can easily be recognised from its densely stellately hairy leaves, and the seeds are appendaged with a small scale and a filiform process. *Mollugo Cerviana*, Ser., is very conspicuous on account of its numerous filiform branches and narrow leaves in whorls.

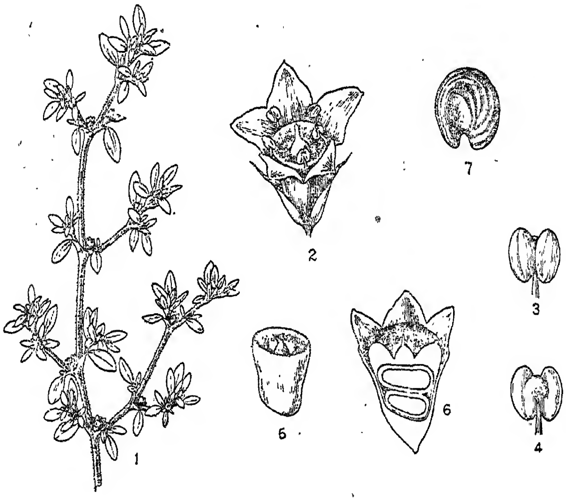


FIG. 386. *Trianthema triquetra*, Rottl. 1, branch; 2, flower; 3, anther, front; 4, anther, back; 5, fruit; 6, fruit cut longitudinally; 7, seed.

Characters of the Family.—All the plants of the family are herbs, annual or perennial. Leaves are simple, fleshy, opposite, alternate or falsely whorled. Flowers solitary or cymose, bisexual and without petals. Calyx is five-lobed. Stamens are definite or indefinite. Ovary is superior, two to five-celled. Fruit is a capsule with circumcissile or dorsal

dehiscence. Seeds, small, reniform, compressed, with endosperm.

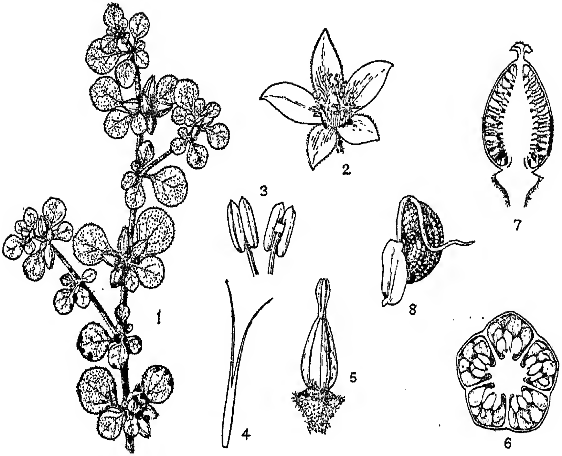


FIG. 387. *Mollugo lotoides*, O. Kze. 1, branch; 2, flower; 3, stamens; 4, staminode; 5, pistil; 6, fruit cut across; 7, fruit cut vertically; 8, seed with appendage.

UMBELLIFERÆ

This family contains several species of plants of some

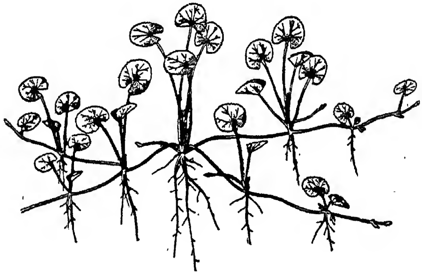


FIG. 388. *Centella asiatica*, Urban.

economic importance. As examples of this family we may choose *Centella asiatica*, Urban, and *Coriandrum sativum*, L.

The species *Centella asiatica* is a weed occurring in moist situations. It is a herb with prostrate trailing stems, rooting at the nodes. The leaves are alternate, exstipulate, orbicular or reniform, entire or crenate, palmately nerved and cordate at the base, with long petioles.

Flowers are small, sessile, in simple 3 to 6 flowered umbels; bracts are small ovate and embracing the flowers. The calyx is truncate with five minute teeth. Petals are reddish, five, epigynous. Stamens are five, epigynous, alternating with the petals. Disk is elliptic. Ovary is inferior, 2-celled and with one pendulous ovule in each cell. Fruit is laterally compressed and breaks into two mericarps with 7 to 9 ridges with reticulations between.

The coriander plant is largely cultivated. It is a much branched glabrous herb with decompound leaves. The segments of the lower leaves are ovate or lanceolate and those of the upper are linear. The petioles have sheaths at the base.

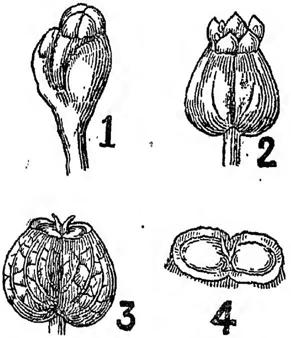


FIG. 389. *Centella asiatica*, Urban. 1, Inflorescence; 2, flower; 3, fruit; 4, disc.

Flowers are in compound umbels and the outer flowers are more conspicuous as they have larger petals; bracteoles are filiform. There are five, small, unequal calyx teeth. Petals are white or white tinged with red, unequal, emarginate or deeply bifid, with a slight median fold or not, epigynous. Stamens are five, alternating with the petals and epigynous. The fruit is subglobose with ridges and faint oil canals or vittæ, breaking into two mericarps; the mericarp is concave on the inner face and has one penduous seed.

Umbelliferæ contain several species of economic importance. The species *Carum copticum*, Benth and Hook, which yields thymol, and the plant *Cuminum cyminum*, L., whose

fruits are used as a condiment belong to this family. The strong-smelling gum-resin asafœtida is obtained from a species of this family, *Narthex asafœtida*, and from others belonging to the genus Ferula and its allies, also of this family.

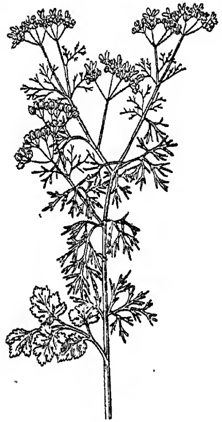


FIG. 390. *Coriandrum sativum*, L.

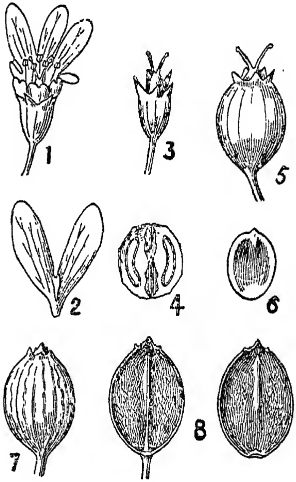


FIG. 391. *Coriandrum sativum*, L. 1, Flower; 2, petal; 3, ovary; 4, section of ovary; 5, fruit; 6, seed; 7, mature fruit; 8, mericarps.

Characters of the Family.—The plants of this family are mostly herbs with alternate simple or compound leaves, having petioles dilated at the base. Flowers are bisexual and in umbels, simple or compound, calyx is reduced to five minute teeth. The corolla is epigynous consisting of five free petals, inserted outside an epigynous disk, caducous. Stamens are five, epigynous, alternating with the petals and with filaments inflexed in bud. Ovary is inferior, 2-celled and with one pendulous ovule in each. Fruit is dry, breaking into two mericarps. Seeds are with endosperm.

RUBIACEÆ

In *Morinda tinctoria*, Roxb., we have a good example of this order. It is a small tree with thick white irregularly

furrowed bark and crooked branches and young branches triquetrous. Leaves are opposite, simple, shortly petioled with connate interpetiolar stipules ; the leaf blade is glabrous, elliptic or elliptic oblong, with entire margin and an acute or subacuminate apex.

Flowers are white and are collected together in heads borne by long peduncles that are leaf-opposed. The calyces of all the flowers are fused together, only a small portion at the top being free. The corolla is superior, tubular with five lobes. Stamens are five, epipetalous and included.

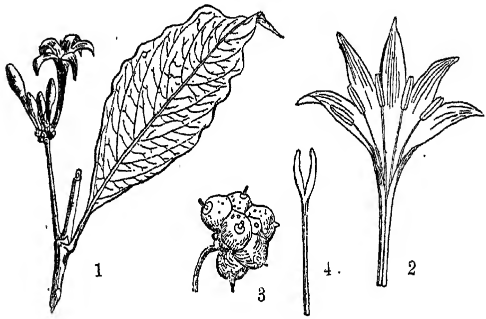


FIG. 392. *Morinda tinctoria*, Roxb. 1, node ; 2, corolla ; 3, fruit; 4, style.

The fruit is globose, fleshy and it consists of the fused enlarged calyces of all the flowers, with many one-seeded drupelets or pyrenes. Seeds have endosperm. The styles are long in some and short in others.

Oldenlandia umbellata, L., is a common herb of this family which may be examined next. This is an annual with numerous branches and linear, sessile, opposite leaves. The interpetiolar stipules are cut into bristles. Flowers are borne by long axillary peduncles, as cymose umbels. Flowers are tetramerous and the ovary is inferior, two-celled, with numerous ovules. Fruit is a globose capsule with persistent distinct calyx teeth on its top. Seeds are small and many.

Other species of common occurrence are the following :—
Oldenlandia paniculata, L., *O. aspera*, DC., *O. Heynei*, Br., *Randia dumetorum*, Lamk., *Canthium parviflorum*, Lamk.,

and *Spermacoce hispida*, L. *Randia dumetorum*, Lamk., has large white flowers on short branches and it is a shrub armed with decussate spines and has large ovoid or ellipsoid fruits. *Canthium parviflorum*, Lamk., is a low shrub with sharp axillary spines, met with everywhere in scrubby jungles and waste places. Flowers of this plant are greenish white and the fruit is a didymous orange-yellow drupe. One of the most widely distributed weeds of the cultivated land is *Spermacoce hispida*, L. It is a prostrate herb with roughly hairy quadrangular stems and flowers are clustered at the nodes within the stipular cup. The fruit is a hairy capsule with two dark brown plano-convex seeds.

FIG. 393. *Oldenlandia paniculata*, L. 1, branch; 2, node; 3, corolla; 4, top view of fruit; 5, fruit cut across.

Characters of the Family.—This is a tropical family and it has many species (about 4,000). The plants of this order consist of trees, shrubs and herbs, and vary very much in their habit. Leaves are opposite or whorled, simple with interpetiolar stipules. Flowers are regular, tetra- or penta-merous with an inferior two to ten-celled ovary. Fruit may be a berry, capsule or a drupe. Plants of this family are easily recognized by the interpetiolar stipules, opposite leaves and the inferior ovary.

COMPOSITÆ

The common weed *Tridax procumbens*, L., introduced into India from South America is widely distributed and so it may be selected as a representative of this large family.

This plant is a perennial herb with hairy straggling branches, some of them ending in heads. Leaves are opposite, simple, ovate or ovate-lanceolate with irregularly toothed

margins and an acute apex, and is covered with scattered hairs on both sides. Heads are solitary on long peduncles, heterogamous and rayed. The receptacle is flat or convex and it is paleate. The outer involucral bracts are hairy outside and

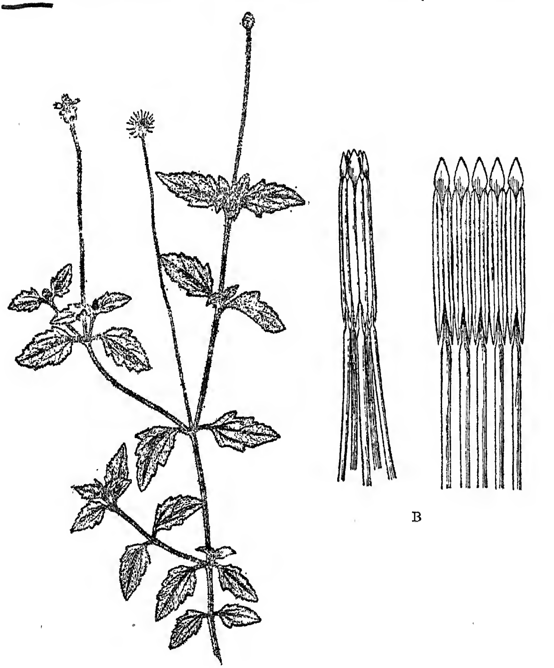


FIG. 394. *Tridax procumbens*, L. A, branch; B, stamens with syngenesious anthers.

shorter than the inner membranous ones. The ray flowers are all female with light yellow, or cream-white ligulate corollas that are deeply three partite. The disc flowers are and tubular. The calyx is represented by a pappus which consists of feathery bristles. The corolla is bell-shaped and five-lobed. Stamens are five, epipetalous and the anthers are syngenesious, sagittate with "short acute auricles" at the base of the lobes. Ovary is inferior, one-celled and one-ovuled and style arms of the tubular flowers

are hairy only on the inner and upper surface. Fruit is an oblong achene, silkily hairy and crowned by the persistent feathery bristles of the pappus.

Vicoa auriculata, Cass., is another common herb of very wide distribution. This is an erect rigid herb with numerous ascending slender branches. Leaves are sessile, oblong or oblong-lanceolate, dilated and auricled at base and hairy on both sides. Heads are heterogamous, rayed and on long peduncles. Involucral bracts are many-seriate, slender, linear, membranous, the outer being shorter. The receptacle is flat, epaleate. Corollas of the ray flowers are ligulate; ligule yellow, long, three-toothed at the free end, and that of the disc flowers are tubular. Anthers are syngenesious and bear tails at the base of the lobes. Achenes are small, covered with scattered hairs and have pappus hairs (no pappus hairs in the achenes of ligulate florets).

Vernonia cinerea, Less., is another herb of very wide distribution. The leaves of this plant are very variable in shape and hairiness. Heads are homogamous, small and are in lax terminal corymbs. All the flowers in a head are tubular and the involucre bracts are in many series, linear lanceolate, awned. Corolla of the tubular flowers is pink. The achenes are clothed with short white hairs and have two rows of pappus hairs.

Many species of Blumea are also found widely distributed in South India. *B. amplectens*, DC., *B. bifoliata*, DC., and *B. Wightiana*, DC., are quite common. The flower-heads in Blumea are heterogamous, anthers have tailed bases and the pappus is one-seriate. In wet situations *Eclipta alba*, Hassk., is sure to be found. The heads in this plant are heterogamous and the achenes of the disc are all thick and they are covered with some kind of excrescences.

Lactuca Heyneana, DC, is a troublesome weed of the waste places and it is easily recognized by the pinnatifid radical leaves, and the numerous erect branches terminating in long cylindrical narrow heads which consist of all ligulate flowers. Another weed, a native of America, now found in South India is *Lagascea mollis*, Cav. It is a slender, softly hairy herb, gregarious in habit and the heads are compound consisting of clusters of small heads. Flowers are all tubular.

Xanthium strumarium, L., is another troublesome plant growing in beds of tanks and paddy fields when they lie fallow. Flowers are monœcious. The heads are either of hermaphrodite flowers (then they are sterile) or of female flowers which are always fertile. The female head consists of two flowers. The fruit is two-beaked and it consists of two achenes completely within the involucral bracts grown and covered with prickles.

Characters of the Family.—This family embraces over 9,000 species and is one of the largest among the flowering plants, and it is widely distributed throughout the world.

All the members of this family are herbs and shrubs, with usually exstipulate, alternate (rarely opposite) leaves. Flowers small, sessile on the dilated end of the peduncle and enclosed by bracts (involucres). The heads may consist of all tubular bisexual flowers, or the ray flowers may be ligulate and female or neuter, and the disc flowers tubular. Calyx tube is adnate to the ovary and the upper free portion is either absent or it consists of pappus hairs or bristles. The corolla is epigynous, ligulate in ray and tubular in disc flowers. The tubular corolla is bell-shaped, five-lobed and lobes have marginal veins. Stamens are five, epipetalous, with syngenesious anthers and free filaments, anther lobes may be tailed or not at the base and the connective is usually produced upwards. The ovary is inferior, one-celled and one-ovuled. Fruit is an achene crowned by the pappus. Seed is erect and without endosperm.

The plants of this order are widespread and they are very aggressive and successful in occupying the land. The compact head, the easy accessibility of the honey to many kinds of insects and the pappus bearing achenes account for this.

√ SAPOTACEÆ

Bassia longifolia, L., will serve as a type for this family. It is a large tree abounding in milky juice and the leaves are clustered near the ends of branches. Leaves are simple, alternate, stipulate, with linear-lanceolate, entire, acute, glabrous blades.

Flowers are clustered like the leaves at the ends of branches. The calyx consists of four sepals in two whorls, the

outer two enclosing the two inner. Corolla is fleshy and six to twelve-lobed, campanulate. Stamens are epipetalous, sixteen to twenty in two rows one above the other; anthers are lanceolate with connectives produced above. Ovary is densely clothed with fine hairs and six or more-celled. Style is long.

Fruit is a berry, somewhat round or oblong with one or two seeds. Seeds have brown polished testa and endosperm.

Two species of Mimusops are fairly common; *M. Elengi*, L., is grown as an ornamental tree and *M. hexandra*, Roxb., is found growing wild in all scrubby jungles and low hills. The flowers of Mimusops have staminodes and the calyx consists of six or eight lobes.

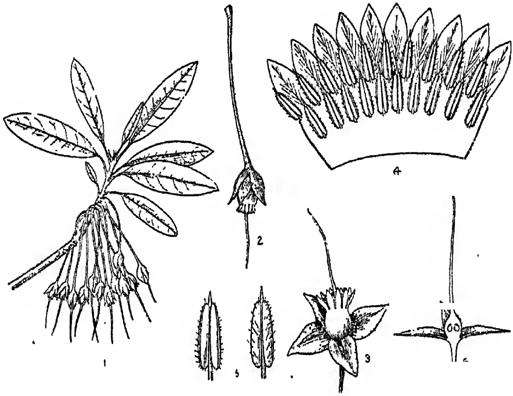


FIG. 395. *Bassia longifolia*, L. 1, branch; 2, flower bud; 3, open flower; 4, corolla and stamens; 5, anthers; 6, pistil.

Bassia malabarica, Bedd., is very common on the West Coast, and differs from the other Bassia in having a corolla hairy both in and out, a glabrous ovary, and lanceolate fruit which is glabrous.

Characters of the Family.—All the members of this family are trees, abounding in milky juice. Leaves are thick, and clustered near the ends of branches. They are simple, alternate, and usually exstipulate (if stipulate, stipules are small and they fall away very soon). Flowers are small, regular, bisexual, axillary and crowded at the ends of

branches. The calyx is four to eight-lobed and the corolla is monopetalous with twice or four times the number of calyx segments. Stamens vary in number from twelve or sixteen to forty, one, two, or three-seriate ; staminodes are present in some genera. Ovary is superior, two to eight-celled, but with solitary ovules in each. Fruit is a berry with one to eight seeds. Seeds are ellipsoidal, usually with a polished testa and a long hilum and without endosperm.

APOCYNACEÆ

The widely distributed spiny ever-green *Carissa spinarum*, L., will serve as a type. It is a low spreading shrub abounding in milky juice and with zigzag branches branching in a cymose manner and bearing bifurcating sharp spines. The leaves are opposite, exstipulate, short petioled, oblong or oblong-elliptic, coriaceous and glabrous (though sometimes slightly hairy).

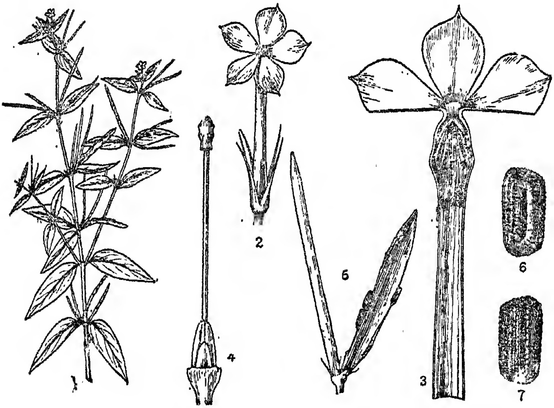


FIG. 396. *Vinca pusilla*, Murr. 1, branch ; 2, flower ; 3, corolla and stamens ; 4, pistil ; 5, fruit ; 6 and 7, seeds.

Flowers are white and in simple cymes or clusters of corymbose cymes. The calyx consists of five very narrow lobes. The corolla is hypocrateriform, with five lanceolate acuminate lobes, twisted to the right in the bud. There are

five epipetalous stamens with very short filaments. Ovary is two-celled with two ovules in each cell.

Fruit is a berry with four seeds, dark purple when ripe.

Vinca rosea, L., is a garden plant grown everywhere and it differs from the above in some respects. Flowers arise in pairs from the axils of leaves and the corolla is hypocrateriform, white or pink in colour. Calyx consists of five very narrow lanceolate lobes. The corolla tube is slightly swollen at the throat just below the attachment of the limbs. Stamens are five, inserted on the tube just in the dilated portion of the tube. Filaments are very short and the anthers just lying close to the stigma, but free from it. Ovary consists of two free carpels and there are two glands alternating with the carpels; style is long, filiform but the stigma is large, drum shaped, or hour glass shaped, with a hyaline frill at the base all round. The fruit consists of two follicles with small rugose black seeds.

Vinca pusilla is a weed resembling *Vinca rosea* very much in all its parts, but only smaller.

Wrightia tinctoria, Br., is a small deciduous tree with milky juice. Flowers are white and in terminal diffuse dichotomous cymes. The corolla has fimbriate scales and five sagittate anthers united so as to form a column adhering to the stigma. The fruit consists of two follicles having linear hairy comose seeds.

Nerium odorum, Soland., is another shrub very commonly grown for its flowers. Leaves are in whorls of three, lanceolate and the flowers are pink, and in terminal panicles or irregular dichotomous cymes. Both the corolla and the connective have appendages. Fruit consists of two follicles and seeds are hairy and comose.

Characters of the Family.—The members of this family are trees, shrubs (erect, or climbing) and herbs. They usually contain a milky juice. Leaves are simple opposite or whorled and entire. Flowers are regular, bisexual and in cymes. The calyx is deeply five-toothed and the lobes are imbricate in bud. Corolla is tubular, rotate or hypocrateriform, five-lobed and lobes twisted. Stamens are five, epipetalous, with very short filaments; anthers are usually sagittate. Ovary is usually two-celled, united or separated

into carpels. Fruit is a berry or a follicle. Seeds are with coma or wing, or without these.

ASCLEPIADEÆ

Calotropis gigantea, R. Br., is a member of this order. This plant is a shrub found all over the country, and abounds in milky juice. The whole plant is covered with appressed white cottony tomentum, which can easily be rubbed off. Leaves are large, opposite, exstipulate, sessile or very shortly petioled, elliptic-oblong to obovate-oblong, thick, entire and the base narrow or cordate.

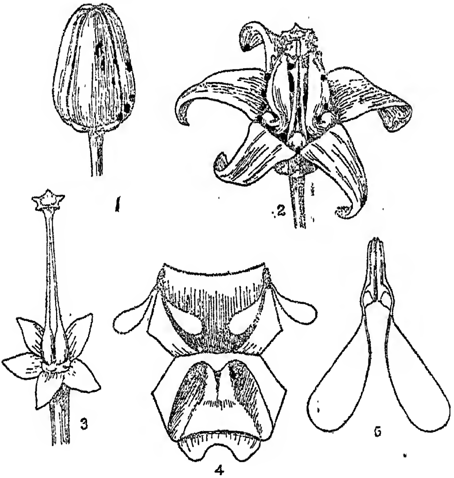


FIG. 397. *Calotropis gigantea*, R. Br. 1, flower bud; 2, flower; 3, pistil; 4, anther; 5, pollinium.

Flowers are large purple or bluish pink and arranged in lateral umbels; pedicel is fine and covered with cottony wool. The calyx is five-partite, and the segments are short and triangular. The corolla is rotate, five-lobed; lobes are broadly triangular, acute and valvate in bud. The stamens are united so as to form a column and this column has five coronas in the form of laterally compressed thick plates; anthers are broad, membranous, united with the pentagonal stigma. Pollen is massed together as pollen masses, and each

anther-cell has a single pendulous pollinium. The ovary is two-celled, carpels are free with free styles, but with a large single pentagonal stigma.

The fruit consists of a single large follicle (very rarely two) containing comose flat seeds.

Some of the members of this family are met with in thickets and hedges as twiners. For instance *Daemia extensa*, Br., is a frequently seen twiner with flowers having both corolline and staminal coronas, and follicles covered with soft spines. *Leptadenia reticulata*, W. & A., is another coarse climber with clear or slightly yellow acrid juice, and opposite, glabrous, coriaceous leaves. The flowers have both corolline and staminal coronas, and the petals have a small hairy process at their tips on the inner face.

The genus Ceropegia is a very striking one on account of its corolla, which is tubular, inflated below and above, but ending above in five lobes which cohere in different ways.

There are a number of plants of this order that have adapted themselves to a xerophytic life. The genus Hoya has very fleshy leaves and the species thrive even under very dry conditions. *Sarcostemma brevistigma*, W. & A., *Boucerosia umbellata*, W. & A., and *Caralluma adscendens*, Br., have very fleshy green stems without leaves and, even when developed, they appear when young as small scales and then drop off. The first one is a creeper with a leafless cylindrical green stem and white flowers in umbels, and the other two are small plants with very succulent square green stems and large flowers.

Characters of the Family.—This is a large order consisting mostly of twining shrubs and herbs with a milky juice. Leaves are opposite, exstipulate, and simple. Flowers are regular, symmetrical, pentamerous and in umbels. The calyx is usually divided down to its base into five small segments and the corolla is five-lobed, rotate or tubular and in some genera provided with corona. Stamens are five and the filaments are united so as to form a fleshy tube and with outgrowths at the back (corona); anthers are free or united to the stigma; pollen grains are found in masses (pollinia) and each pollinium may have a stalk (caudicle) and a gland (corpuscle).

The ovary is superior of two one-celled free carpels; ovules are many. Fruit consists of two follicles, but often only one is developed, and seeds are flat and comose.

The two plants *Trichodesma indicum*, Br., and *Heliotropium ovalifolium*, Forsk., are typical examples of the family.

Trichodesma indicum, Br., is a low annual with many hispid branches, flourishing in dry situations. Leaves are simple, opposite and also alternate, sessile, exstipulate, linear-oblong or oblong-lanceolate, entire and cordate at base; the upper surface is covered with stiff hairs springing from tubercles that appear as white circles when dry and the lower surface is more hairy, but less harsh.

Fig. 398. A branch of *Trichodesma indicum*, Br.

Flowers are solitary, leaf-opposed, with pale blue corollas. The calyx is deeply five-lobed, covered with long stiff hairs and grows in the fruit; the lobes are lanceolate, acute and prolonged at the base and hence hastate or auricled. The corolla consists of a short tube and five spreading lobes that are somewhat ovate triangular in shape; the lobes have a brown patch at their bases and end in pointed processes which are short or long (then twisted),

Stamens are five, epipetalous, with very short filaments; the anthers are oblong or lanceolate and united into a cone and are hairy outside; the connectives are broad outside, produced beyond the apex and are twisted together. Ovary is four-lobed and four-celled with a single ovule in each and the axis is very prominent. Style is long.

The fruit is conical, and the four lobes separate from the axis as nutlets, leaving four pits; the nutlets are grey and smooth at the back and the inner surface is rugose.

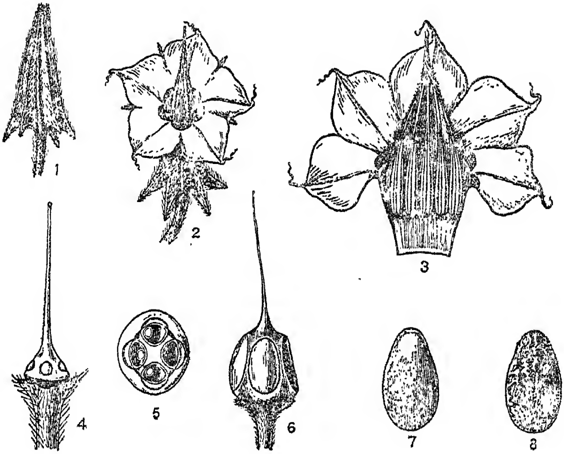


FIG. 399. *Trichodesma indicum*, Br. 1, flower bud; 2, open flower; 3, corolla and stamens; 4, pistil; 5, pistil, transverse section; 6, fruit; 7, back of nutlet; 8, inner-face of nutlet.

Heliotropium ovalifolium, Forsk., is a herbaceous plant with numerous softly hairy, prostrate or erect branches flourishing in clayey soils, such as the beds of tanks and paddy fields when they lie fallow. Leaves are alternate, simple, exstipulate, shortly petioled, obovate or elliptic, and softly densely hairy on both sides. Flowers are white, small and are two-ranked on one side of an axis, which is really a scorpioid cyme; and this is why the inflorescence is coiled at the free end. The calyx is persistent in fruit, five-partite and one lobe is very much larger than the other four; corolla

is tubular, hairy outside and also with a few hairs at the throat. Stamens are five, epipetalous; filaments are very short and the anthers are lanceolate. The ovary is four-celled and four-ovuled. There is no style and the stigma is conical with a few hairs at the top. The fruit breaks into four nutlets.

Other species of Heliotropium occurring in South India are *H. indicum*, L., *H. supinum*, L., and *H. marifolium*, Retz.

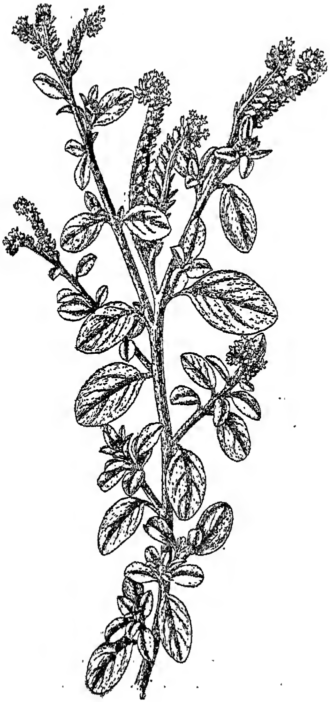


FIG. 400. *Heliotropium ovalifolium*, Forsk.

Coldenia procumbens, L., is a diffuse prostrate herb usually found in paddy fields, easily recognized by the

branches which are lying quite flat on the ground with crisped hairy leaves and solitary axillary flowers.

Some members of this family, *Cordia Myxa*, L., *C. monoica*, Roxb., and *C. Rothii*, R. & S., are small deciduous trees commonly met with in the forests of the plains and low hills. The fruit of Cordia is a drupe with gummy pulp.

Ehretia buxifolia, Roxb., is a very common shrub growing in scrubby jungles of the plains.

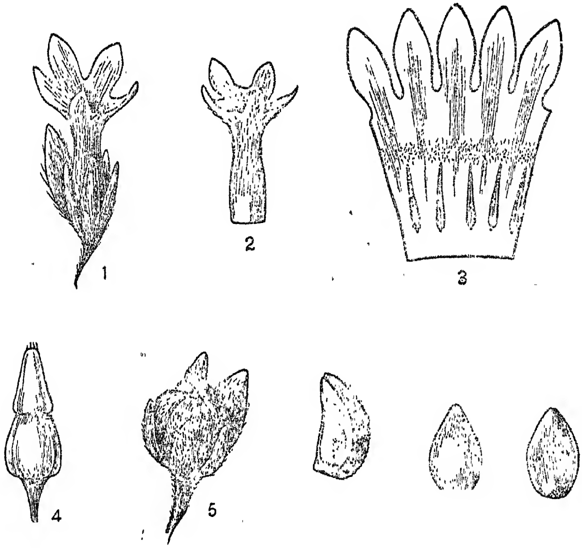


FIG. 401. *Heliotropium ovalifolium*, Forsk. 1, flower; 2, corolla; 3, corolla laid open to show stamens; 4, pistil; 5, fruit; 6, segment; 7, seeds

Characters of the Family.—The plants are herbs, shrubs or trees. Leaves are simple, alternate (rarely opposite) and exstipulate. Inflorescence is usually a suppressed dichotomous cyme. Flowers are regular and bisexual. The calyx is five-partite, persistent, the corolla is tubular, five-lobed. Stamens are five with short filaments, epipetalous. Ovary is two- to four-celled with one ovule in each cell. Fruit is either a drupe or it divides into four nutlets.

This order is a cosmopolitan one with many species, widely spread in temperate climates and in the tropics.

CONVOLVULACEÆ

The small herb *Evolvulus alsinoides*, Wall., growing amidst grass in waste places may be chosen as a type. This is a perennial and produces numerous wiry stems covered

FIG. 402. *Convolvulus arvensis*, L.

with long, soft hairs. Leaves are small alternate, exstipulate, variable, elliptic-oblong and densely clothed with soft appressed hairs on both sides. Flowers are solitary, peduncle jointed. The calyx consists of five, narrow, free sepals densely covered with silky hairs. The corolla is rotate, blue

Stamens are five, epipetalous. Ovary is superior, two-celled and four-ovuled ; styles are two, distinct and bifid at the tip.

Fruit is a globose four-valved capsule containing four glabrous seeds.

The genus Ipomœa is quite characteristic of this family and any one of its numerous species may be examined. Most of these are twiners and a few are prostrate ones. The calyx is of five unequal, free sepals (quincuncially) imbricate and, in some, enlarged in fruit. The corolla is monopetalous, funnel or bell-shaped, and the lobes are plicate, and this is well seen even in an open flower. Stamens are five, equal or unequal, epipetalous ; filaments in some are dilated at the base. Ovary is two-or four-celled and four-ovuled ; style is filiform with a bi-globose stigma. Fruit is capsular, four-valved and four-seeded. Seeds are smooth, velvety, or even hairy.

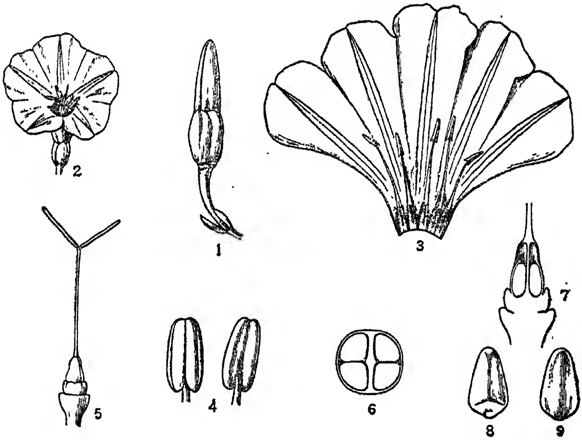


FIG. 403. *Convolvulus arvensis*, L. 1, flower bud; 2, flower; 3, corolla laid open to show stamens; 4, anthers; 5, pistil; 6, transverse section of fruit; 7, longitudinal section of ovary; 8 and 9, seeds.

Convolvulus arvensis, L., and *C. Rottlerianus*, Chois., are also very common in certain regions. The former is a low twiner with underground branches and it is a persistent weed. Its flowers and fruits are like those of Ipomœa, but the stigmas are elongate instead of bi-globose.

The parasitic plants *Cuscuta reflexa*, Roxb., and *C. chinensis*, Lamk., are members of this family.

Characters of the Family.—These are herbs or shrubs, mostly twining, though a few are erect. Leaves are simple, alternate exstipulate, and petiolate. Flowers are in cymes or solitary' regular and bisexual. The sepals are five, free and imbricate' The corolla is usually showy, rotate, bell-shaped or funnel-shaped. Stamens are five, unequal and epipetalous. The ovary is superior, two or four-celled with four ovules. Fruit is a capsule. Seeds are with scanty endosperm, and folded foliaceous cotyledons.

This is another order cosmopolitan in its distribution though abundant in the warmer regions.

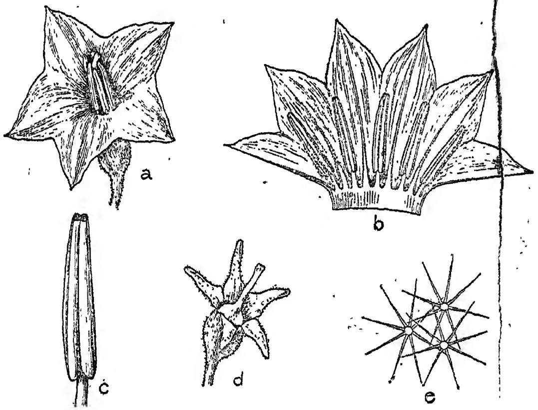


FIG. 404. *Solanum Melongena*, L. *a*, flower; *b*, corolla and stamens; *c*, anther; *d*, pistil and calyx; *e*, stellate hairs.

SOLANACEÆ.

The widely cultivated brinjal plant *Solanum Melongena* L., is a good type of the family. This plant grows to a height of three to six feet and the whole plant is thickly coated with stellate hairs, and it is also armed with prickles. Leaves are alternate, exstipulate, petiolate, ovate, sinuate or lobed, covered below with stellate hairs and with prickles on the veins, and unequal at base.

Flowers are in extra-axillary helicoid cymes, only one flower being perfect. The calyx is five-lobed, stellately hairy

outside, and it is persistent and grows with the fruit and sometimes also prickly. Corolla is violet blue, rotate, five-lobed (sometimes six to eight), stellately hairy outside between the folds and on the plaits. Stamens are equal to the corolla lobes, epipetalous; filament is short, and anthers are long and open by apical pores. Ovary is superior, two-celled and many ovuled.

Fruit is a two-celled berry with many compressed flat seeds.

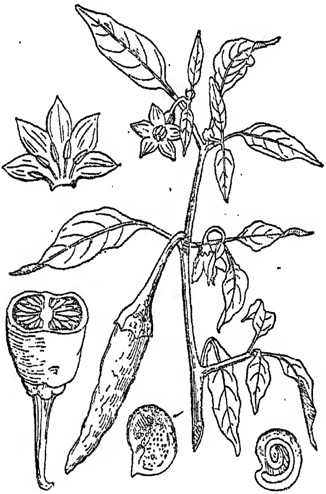


FIG. 405. *Capsicum frutescens*, L.

This plant exhibits a certain amount of variation in its flower under cultivation. On the same plant we find corollas with five, six, seven or eight lobes and as many stamens. The fruit shows many irregular cavities due to unequal growth and development of the placenta.

Solanum xanthocarpum, Schrad and Wendel., is a very prickly plant with diffuse branches very much like the brinjal plant in the structure of its flowers, but the fruits are smaller.

Solanum torvum, Sw., is a shrub without prickles and the flowers are white.

Solanum nigrum, L., is also a common plant easily recognised by the extra axillary umbellate cymes of red or black round berries. The berries are sweet and are eaten in this country, but they are said to be highly poisonous in England.

Capsicum frutescens, L., and *C. annum*, L., and *Nicotiana Tabacum*, L., are under cultivation. In all these, the anthers dehisce longitudinally and the fruit is a berry in the first two and a capsule in the third.

Physalis, Withania and Nicandra have persistent enlarged membranous calyces covering the fruit.

Characters of the Family.—The members of this family are either herbs or shrubs. Branches in some species are sympodial. Leaves are alternate, simple, petiolate and exstipulate. Flowers are regular, pentamerous and bisexual and in extra-axillary or lateral cymes. The calyx is inferior five-lobed persistent and even accrescent. The corolla is monopetalous, rotate or funnel shaped, with five lobes. Stamens are five, epipetalous with very short filaments and anthers dehiscing by apical pores or longitudinally. Ovary is superior, two-celled. Fruit is a berry or a capsule. Seeds are without endosperm, usually compressed.

SCROPHULARINEÆ.

Many species of this family occur as weeds in moist situations. The weeds *Stemodia viscosa*, Roxb., *Herpestis*

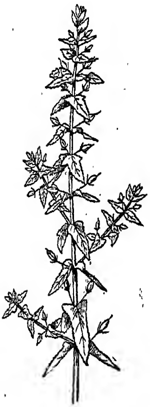


FIG. 406. A branch of *Stemodia Viscosa*, Roxb.

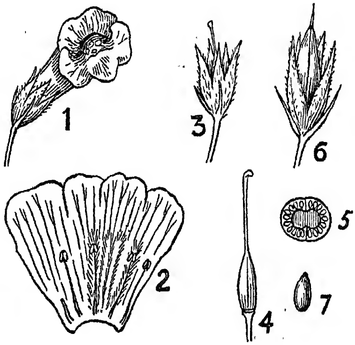


FIG. 407. *Stemodia Viscosa*, Roxb. 1, flower; 2, corolla; 3, calyx and ovary; 4, ovary and style; 5, ovary cut across; 6, fruit; 7, seed.

Monniera, H.B. & K. and *Bonnaya veronicæfolia*, Spreng., may be examined as types of this family.

Stemodia viscosa, Roxb., occurs in paddy fields. It is a much branching, erect, somewhat aromatic plant with angular

stems and branches. The whole plant is pubescent with glandular hairs.

Leaves are opposite or whorled, variable in size, sessile, cordate, and somewhat amplexicaul at base, oblong, usually tapering towards the apex, acute, with a serrulate or sub-entire margin. Flowers are axillary, solitary or in terminal few-flowered racemes. Pedicels are fine, slender and there are two linear bracteoles. The calyx is 5-partite and the lobes are narrow lanceolate, ciliate and glandularly hairy. The corolla is tubular, bilabiate, violet and glabrous, the upper lip is broad entire or emarginate and the lower lobe with three emarginate or rounded lobes. There are four epipetalous stamens two long and two short; the anthers are distinct and stalked. Ovary is glabrous with a long style and a bifid stigma, two-celled and many-ovuled. The fruit is a 4-valved capsule. Seeds are minute oblong-elliptic.

FIG. 408. *Herpestis Monniera*, H.B & K.

Herpestis Monniera, H.B. & K., is a glabrous succulent creeping herb found in ditches and in margins of ponds or marshy situations. The main stems are rooting at the nodes and creeping and the secondary branches are erect and numerous.

Leaves are opposite, decussate, sessile, oblong to obovate or spathulate, entire with minute black dots. Flowers are solitary, axillary with slender pedicels. The calyx is 5-partite, and one lobe slightly longer than the others. The corolla is light blue or almost white, with nearly round equal

lobes. Stamens are epipetalous, didynamous with distinct anthers. Ovary is 2-celled and many-ovuled ; the style is

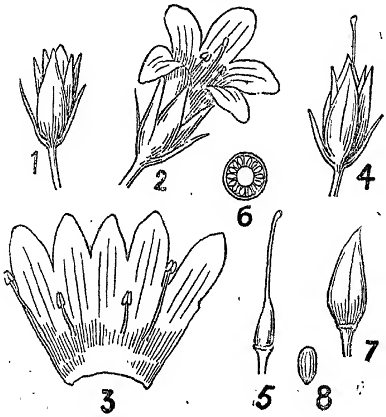


FIG. 409. *Herpestis Monniera*, H.B. & K. 1, flower bud; 2, flower; 3, corolla; 4, fruit and calyx; 5, ovary; 6, section of ovary; 7, fruit; 8, seed.

slender and the stigma is bifid. Fruit is a 2-celled globose capsule. Seeds are obconic, small.

G. 410. *Bonnaya veronicæfolia*, Spreng.

Bonnaya veronicæfolia, Spreng., is an annual glabrous herb with decumbent or creeping stems rooting at the nodes and with quadrangular ascending branches. Leaves are opposite, exstipulate, subsessile, distantly and shallowly serrate. Flowers are in axillary and terminal racemes. Pedicels are divaricate, short in the flower but elongating in fruit; bracts are small, linear-lanceolate. The calyx is deeply-lobed into five linear-lanceolate acute lobes. The corolla is violet, bilabiate, with two lobes in the upper and three in the lower. There are two perfect stamens and two clavate long yellow staminodes. The fruit is a narrow oblong capsule acute at the tip and glabrous. Seeds are small and truncate at both the ends.

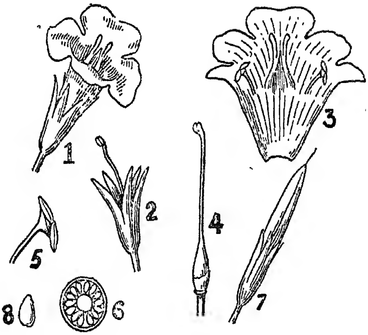


FIG. 411. *Bonnaya veronicæfolia*, Spreng. 1, flower; 2, calyx and ovary; 3, corolla; 4, ovary and style; 5, anther; 6, section of fruit; 7, fruit; 8, seed.

The very common marsh plant *Limnophila gratioloides*, Br., and the weeds of the paddy fields, *Dopatrium nudicaule*, Ham, *D. junceum*, Ham., and *D. lobelioides*, Benth. are also plants of this family. The root parasites *Striga lutea*, Lour., and *Sopubia delphinifolia*, G. Don., are other members of this order.

Characters of the Family.—The plants of this family are, herbs or shrubs, some being partly parasitic on roots. Leaves alternate or whorled and exstipulate. Flowers are bisexual

usually irregular and racemose or mixed in inflorescence. The calyx is persistent, pentamerous. The corolla is tubular, tube long or short, bilabiate, four or five lobed. Stamens are epipetalous four or two and when two with usually two staminodes. Disk is annular or glandular. Ovary is two-celled and many-ovuled. Fruit is a capsule bursting in various ways. Seeds are small and of different shapes.

PEDALINEÆ.

The Gingelly or Sesamum plant may be taken as a type of this family.

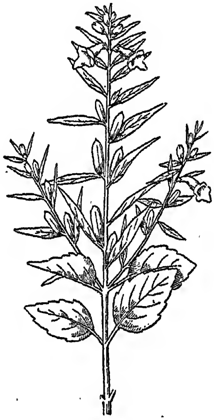


FIG. 412. *Sesamun indicum*, DC.

The plant *Sesamum indicum,* DC., is a softly hairy herb with square stems, and growing to the height of about four feet. The leaves are opposite in the lower portions of the plant, and sub-opposite or opposite in the upper parts. On the same plant the leaves vary, the lower are lobed or pedatisect, the middle are ovate and toothed and the upper narrowly oblong and sub-entire.

The flowers are axillary, solitary with the two lateral flowers often reduced to yellowish gland-like bodies, or in

fascicles of two or three, and with short pedicels. The calyx is small, with five lanceolate lobes. The corolla is large-pinkish or pinkish white with yellow marks inside, tubular ventricose, five-lobed with one lobe slightly larger than the

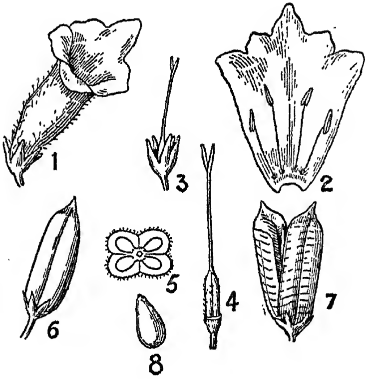


FIG. 413. *Sesamum indicum*, DC. 1, flower; 2, corolla; 3, calyx, ovary and style; 5, section of ovary; 6, 7, fruit; 8, seed.

others, and pubescent. Stamens are four, didynamous and included. The ovary is two-celled, becoming falsely four-celled, and cells many-ovuled.

The fruit is an oblong capsule, hairy and opening by two valves at first and then ultimately four-valved. Seeds are ovate-oblong, compressed, smooth, blackish or brown.

Sesamum prostratum, Retz., occurs on sand hills near the sea on the East Coast. Another species *S. laciniatum*, Klein., is also commonly met with in sandy situations in the Presidency. Both these have deep purple flowers.

Pedalium Murex, L., is another weed of this family and it can be easily recognised by the yellow corolla and the hard pyramidal or oblong-ovoid fruit bearing four spines.

ACANTHACEÆ

The common weed *Ruellia patula*, Jacq., is a good example of this family. It is a much branched herb, with

long internodes and nodes slightly thickened and purple. Leaves are opposite, exstipulate, petiolate, ovate, entire, sparsely hairy on both sides.

Flowers are solitary, axillary, sessile, with two bracteoles. The calyx is divided to its base into five very narrow segments. The corolla is violet pink, monopetalous, tubular below, and funnel-shaped above, with five rounded lobes

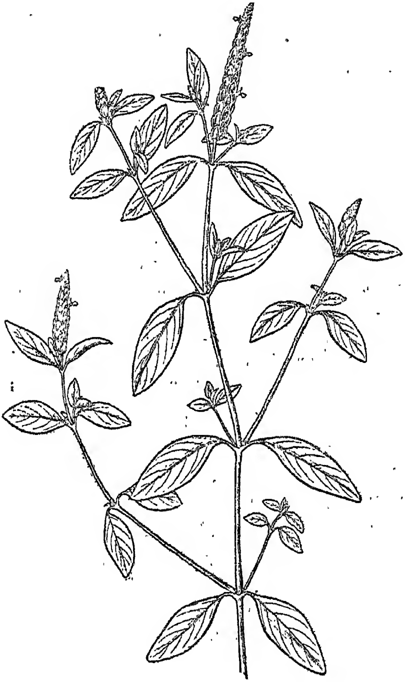


FIG. 414. *Rungia repens,*

twisted in bud to the left, but spreading out in open flower. The stamens are epipetalous, didynamous. The ovary is superior, two-celled and many-ovuled with axile placentation; style long and hairy, stigma bifid but one lobe is very short.

The fruit is a capsule somewhat club-shaped with a mark at the tip which, if wetted, brings about the dehiscence.

Seeds are thin, discoid on hard funicles (retinacula) and there is a line of hairs at the margin.

Rungia repens, Nees, is another plant met with in the bunds of paddy fields and ditches, amidst grass. It is a branched herb with slender glabrous branches. Flowers are in one-sided spikes with bracts and bracteoles. The bracts without flowers are larger than those connected with the flowers and both the bracts have scarious margins. The corolla is two-lipped with two epipetalous stamens. The anther lobes are placed one above the other and the lower lobe has an appendage. The fruit is a small compressed capsule.

Hygrophila spinosa, T. Anders., is another, common, stout, erect herb with many straight branches bearing long spines at the nodes, and growing in moist situations such as ditches amidst paddy fields.

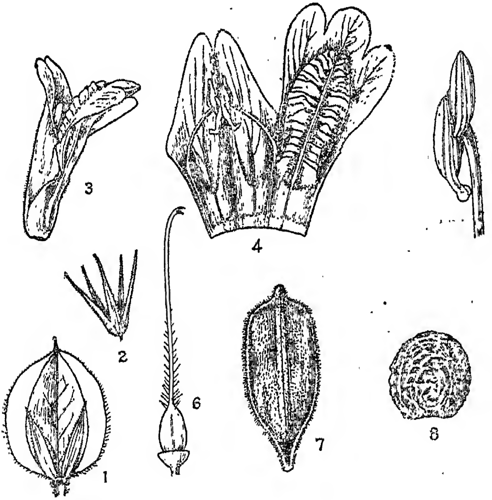


FIG. 415. *Rungia repens*, Nees. 1, bract and bracteoles; 2, calyx; 3, 4, corolla; 5, anthers; 6, pistil; 7, fruit; 8, seed.

Other plants of common occurrence are *Andrographis echioides*, Nees, *Blepharis mollugінifolia*, Pers., *Justicia procumbens*, L., and *Barleria Prionitis*, L. *Andrographis echioides*, Nees, is easily recognised by its inflorescence

consisting of white corollas, glandularly hairy sepals, bracts and bracteoles; *Blepharis molluginifolia*, Pers., has wiry prostrate branches with whorled leaves and solitary flowers with three or four pairs of decussating bracteoles and a corolla with a three-lobed lower tip and without the upper one. In *Justicia procumbens* the flowers are small and in terminal spikes and *Barleria Prionitis* is conspicuous by its regular orange tubular corolla with two stamens and axillary spines.

Characters of the Family.—Plants of this order are herbs or shrubs. Leaves are opposite, exstipulate, simple, and the nodes are somewhat swollen. Flowers are hermaphrodite, regular or irregular, in cymes, spikes or racemes with bracts and bracteoles. The calyx is usually deeply five-lobed and the corolla is equally or unequally five-lobed. Stamens are four or two, epipetalous; anther lobes parallel and near or superposed. Ovary is superior, two-celled and many-ovuled. Fruit is a loculicidally dehiscing capsule. Seeds are many or few, discoid, compressed, smooth or hairy, seated on retinacula (hardened funicles), and there is no endosperm.

LABIATÆ.

The common weed, *Leucas aspera*, Spreng., will serve as a good example of this family.

This is a diffusely branching annual with hairy, square stems. The whole plant possesses a strong smell. Leaves are exstipulate, opposite, sessile or with a very short petiole, linear, coarsely crenate and hairy on both the surfaces.

Flowers are sessile and collected together in congested cymes (verticillasters) in the axils. Bracts are linear, acute with long hairs on the margins. The calyx is monosepalous persistent, tubular, bent and constricted below; the upper portion of the tube is ribbed and hairy, but the lower half is glabrous and membranous; the mouth of the tube is oblique, with the small upper teeth projecting above. The corolla is white and labiate; the upper lip is narrow and very densely woolly outside, and the lower lip is broad, flat, three-lobed, the midlobe being the largest and obovate and the lateral smaller. The stamens are epipetalous, didynamous and included within the upper lip; anthers are red. The ovary

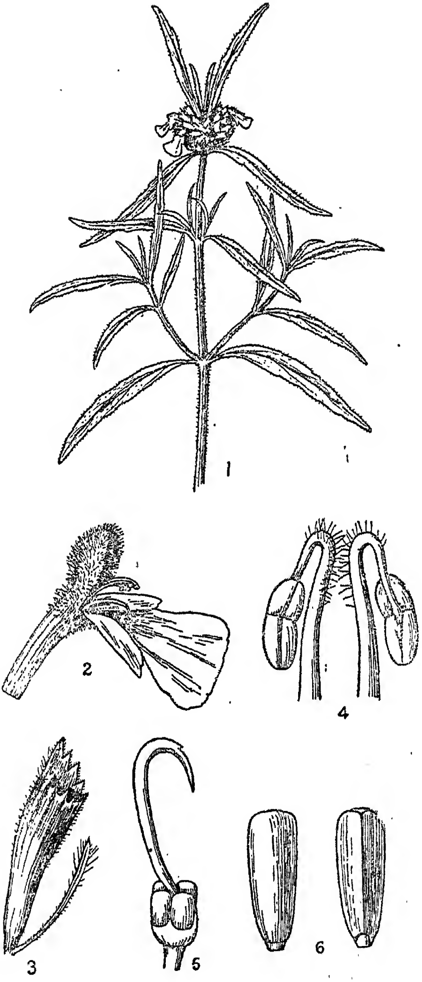


FIG. 416. *Leucas aspera*, Spreng. 1, branch; 2, corolla; 3, calyx and bract; 4, stamens; 5, pistil; 6, nutlets.

is superior, deeply four-lobed and is surrounded by a lobed-disk. The style is long and it rises from the middle of the four lobes (gynobasic).

The fruit consists of four oblong nutlets, rounded at the back and angled inside.

Other plants that are easily procurable are *Ocimum canum*, Sims., *O. sanctum*, L., *O. Basilicum*, L., and *Anisomeles malabarica*, R. Br. All these plants are aromatic. The Ocimums have a labiate corolla with the upper lip broader and four-lobed and a narrow lower lip, and the two-upper stamens have hairy appendages at their base. *Anisomeles malabarica*, R. Br., is a very softly woolly plant with a large, pinkish, two-lobed corolla and the flowers are in distant cymes.

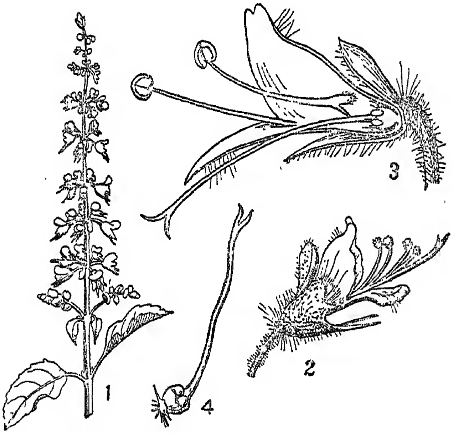


Fig. 417. *Ocimum sanctum*, L. 1, branch; 2, flower; 3, section of flower; 4, pistil.

The species *Moschosma polystachyum*, Benth., is a glabrous plant often met with in wet places, and it is easily recognised by its one-sided whorled inflorescence. Many species of Leucas occur both on the plains and on the hills. In some parts of the Presidency the plant *Leonotis nepetæfolia*, R. Br., is a very conspicuous plant. It has got very large verticillasters, and the corolla is scarlet or deep orange.

Characters of the Family.—The members of this family are mostly scented herbs though a few are shrubby. The axis is quadrangular and hairy. Leaves are exstipulate, opposite or whorled. Flowers are bisexual, irregular, labiate, in cymes or in false whorls (verticillasters). The calyx is monosepalous, persistent, regular or irregular. The corolla is tubular, labiate. The stamens are epipetalous and didynamous or all four equal, and all or only two perfect. The ovary is superior with a lobed disk and a two-fid long slender style, which is apical or gynobasic. Fruit consists of four nutlets.

Achyranthes aspera, L., growing in hedges and thickets all over South India is a representative of this family.

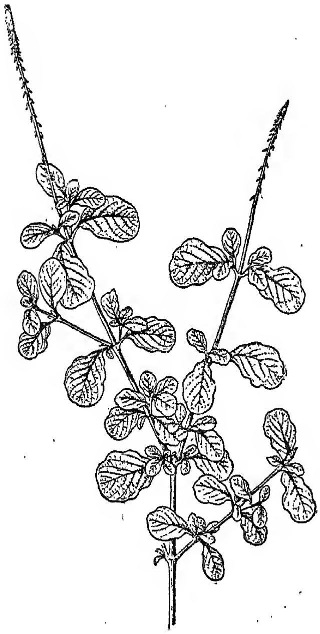


FIG. 418. *Achyranthes aspera, L.*

This plant produces only a few straggling branches and the axis is rounded and striate. Leaves are exstipulate, simple, opposite, petioled, obovate or rotund, and finely hairy on both sides, and margins entire wavy.

Flowers are in terminal spikes, stiffly deflexed and crowded on the axis. Both the bract and the bracteoles are ovate and spinescent, persistent and become hardened in fruit. The perianth consists of five ovate oblong or lanceolate, shining, glabrous sepals, that are greenish or reddish at the edges, with spinescent apex and membranous

margins. These become hardened and persist with the fruit. There are five stamens alternating with five truncate, fimbriate staminodes.

Fruit is indehiscent with a membranous hardened pericarp (utricle). Seed is cylindric.

Amarantus viridis, L., *A. spinosus*, L., and *A. gangeticus*, L., are very common plants; the first two occur as weeds in waste places and the third is largely cultivated. The flowers are generally small, unisexual and monœcious.

Many plants of this order grow as weeds in the fields and the most common ones are the following: *Celosia argentea*, L. (most abundant in dry fields and very conspicuous on account of its glistening white spikes, pinkish at first), *Aerua lanata*, Juss., *A. javanica*, Juss., and *A. Monsonia*, Mart.

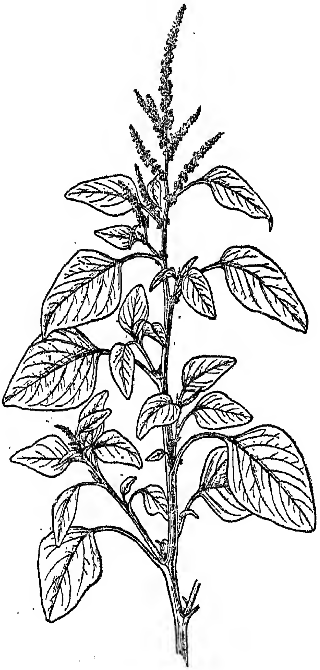


Fig. 419. *Amarantus viridis, L.*

In hedges and in thickets *Pupalia atropurpurea*, Moq., flourishes and it is easily recognisable from its inflorescence, in which the flowers are grouped in threes and the two lateral flowers become hooked spines, and remain attached to the middle one and persist with the fruit, resulting from the middle flower. *Alternanthera sessilis*, Br., is a plant found growing in damp places.

Characters of the Family.—All the members of this family are herbs. Leaves are exstipulate, simple, alternate or opposite. Flowers are hermaphrodite or unisexual, monœcious, in

spikes or clusters. The perianth consists of five scarious, persistent sepals. Stamens usually vary from one to five and staminodes may be present or not. The ovary is one-celled and with one or many ovules that are erect or suspended from a funicle. Fruit is a membranous utricle.

Seeds are usually orbicular, black, polished and compressed; embryo coiled and in floury endosperm.

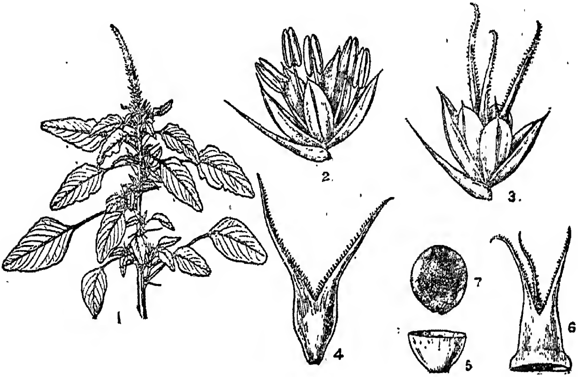


FIG. 420. *Amarantus spinosus* L. 1, branch; 2, male flower; 3 female flower; 4, fruit; 5, base of utricle; 6, upper lid of utricle; 7, seed.

EUPHORBIACEÆ

The family is a large one and the species differ very much in their vegetative parts and even in their flowers. Therefore, it is necessary to select three types at least.

Acalypha indica, L., is a widespread common weed. It is an annual with numerous, long branches. Leaves are alternate with very minute stipules, long-petioled (the younger leaves short-petioled and older long-petioled), ovate, serrate, three nerved at base.

Flowers are unisexual and monœcious, and in axillary elongated spikes. Male flowers are very minute and are clustered towards the apex of the spike, and the female flowers are few at the base, and at the apex of the inflorescence there is a peculiar appendage (a female flower), and sometimes this contains a seed. The male flowers have

four sepals and eight stamens and the female flower is provided with a large, leafy, many-nerved, dentate bract. The ovary is hairy and three-celled, with a single ovule in each cavity.

The fruit is a small hispid capsule and it is concealed by the enlarged bract. Seeds are ovoid, smooth and brownish.

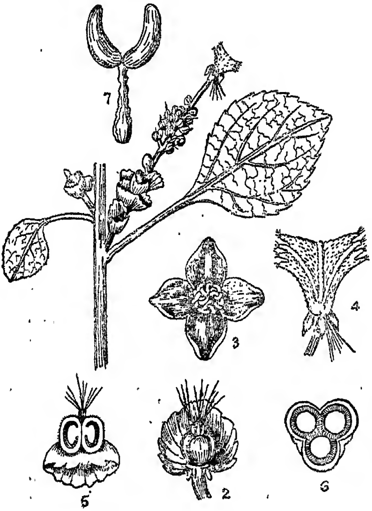


FIG. 421. *Acalypha indica*, L. 1, branch; 2, female flower; 3, flower; 4, terminal female flower; 5, fruit cut vertically; 6, fruit cut across; 7, a stamen.

Another common weed widely distributed is *Phyllanthus maderaspatensis*, L. This plant is a variable annual with numerous branches. In this plant, and also in some other species of Phyllanthus, the branchlets look like pinnate leaves. Leaves are small, alternate and bifarious, shortly petioled with lanceolate peltate stipules, obovate-cuneate, truncate or rounded at apex, often mucronate, and the nerves are conspicuous on the lower surface of the leaf.

Flowers are unisexual, monœcious; male flowers are minute, sessile and clustered in the axils; but the female

flowers are larger, solitary and stalked. The sepals in both are six, obovate, with white margins. Stamens are three and the filaments are united. The ovary is superior three-celled, with three two-lobed styles and two ovules in each cell.

The fruit is a capsule with three lobes. Seeds are somewhat trigonous though rounded at the back.

Euphorbia hirta, L., is an annual with erect or procumbent branches. The whole plant is covered with long rough hairs and it contains a milky juice. Leaves are opposite, short-petioled and with pectinate stipules, obliquely elliptic or oblonglanceolate, dentate, green, or reddish green.

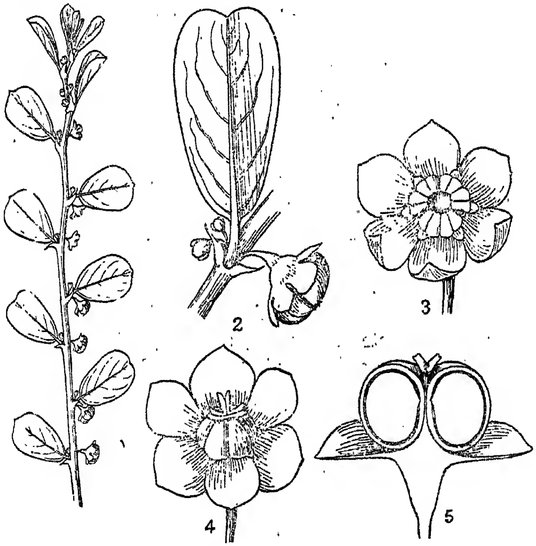


FIG. 422 *Phyllanthus maderaspatensis*, L. 1, branch ; 2, node with a leaf, stipules and flowers; 3, male flower; 4, female flower; 5, fruit cut vertically.

Flowers are unisexual, monœcious and collected together into inflorescences simulating single flowers, and this inflorescence is called a *cyathium*. The cyathiums are crowded and axillary. The cyathium consists of a perianth-like organ or the involucre, which is tubular and five-lobed,

a solitary fruit and a number of stamens within. The single fruit is really a female flower surrounded by a number of male flowers.

Each involucre consists of a tube, five very small limbs with minute glands between them. The stalked stamens found within the involucre and round a stalked ovary are really male flowers, each stalked stamen representing one flower. In every involucre there is a single stalked ovary which is a female flower.

Fruit is a capsule, three-lobed and covered with appressed hairs. Seeds are trigonous, transversely rugose and brown in colour.

There are many species of Euphorbias and they are easily recognized by their Cyathiums. *Euphorbia rosea*, Retz., and *E. corrigioloides*, Boiss., occur in dry open sandy situations. Some of the Euphorbias are big shrubs with cladodes and are typical xerophytes. *E. antiquorum*, L., and *E. tirucalli*, L., are examples.

The Castor plant (*Ricinus communis*, L.), *Jatropha Curcas*, L., *J. glandulifera*, L., *Phyllanthus emblica*, L., *P. reticulatus* Poir., and *Flueggia Leucopyrus*, Willd., are other common plants of this order.

Characters of the Family.—The family includes herbs, shrubs and trees, and many of them abound in milky juice. Leaves are alternate or opposite, stipulate, petiolate (sometimes petioles with glands), and usually simple. Flowers are small, unisexual, monœcious, and arranged in various ways. The perianth is usually single, rarely double. Stamens are few, many or even one. Ovary is superior three-celled with one or two ovules in each cavity. Fruits are capsules, berries or drupes. Seeds are often arillate, with endosperm.

URTICACEÆ

The Jack-fruit and the Banyan tree are good examples of this order.

The Jack tree (*Artocarpus integrifolia*, L.) is a large evergreen tree with milky juice. Leaves are alternate, with large spathaceous, caducous stipules, oblong or elliptic-oblong, shining and glabrous above, coriaceous.

Flowers are monœcious, in spikes, or heads that are covered by large stipules, when young. In the male spike

the flowers have two oblong or spathulate sepals and a single stamen. The female flowers have a tubular perianth which is united below to a concave receptacle, with the ovary at the bottom; the style is lateral. The female spike grows and becomes the fruit, but the male spike falls off.

The fruit consists of an enlarged axis covered with the very much accrescent fleshy perianths and carpels, with hardened flat spinescent apices. (See fig. 297.)

Ficus bengalensis, L., is a large spreading tree, capable of indefinite extension, on account of its aerial roots arising from the branches. All parts of the tree abound in milky juice and young parts are softly pubescent. Leaves are simple, alternate, stipulate (stipules coriaceous and large), oblong or ovate-oblong, entire, obtuse, and three to seven nerved at base.

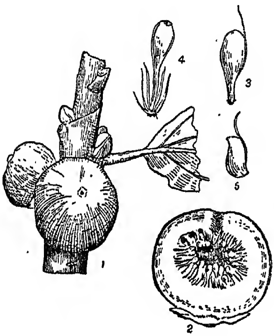


FIG. 423. *Ficus bengalensis*, L. 1, the inflorescence; 2, same cut vertically; 4, gall flower; 3, 5, female flower.

The fig or the young inflorescence consists of male, female and gall flowers lying inside the hollow receptacle, which is usually fleshy. There are many male flowers near the mouth of the receptacle, and each male flower has only one stamen and four sepals. The perianth in the gall flower is similar to that of the male flower. The female flower has four sepals shorter than in the male flower and the style is lateral.

Several species of Ficus are fairly common in South India and the most common ones are *Ficus religiosa*, L., *F. glomerata*, Roxb., *Ficus Tsiela*, Roxb., *Ficus hispida*, L.f., and *F. asperrima*, Roxb.

The small gnarled tree *Streblus asper*, Lour., with its crooked interwoven branches, may be seen in scrubby jungles. Flowers are diœcious.

Dorstenia indica, Wall., is a small herb growing in damp situations on the hills and it is easily recognised by the flat receptacle with both kinds of flowers on it.

MONOCOTYLEDONS

ORCHIDEÆ

Eulophia virens, Brown, is an orchid occurring in dry ground all over the Presidency.

This is a herbaceous, perennial, ground Orchid having a pretty large epigeal conical rhizome (pseudobulb) with long grass-like, plaited leaves possessing a strong midrib.

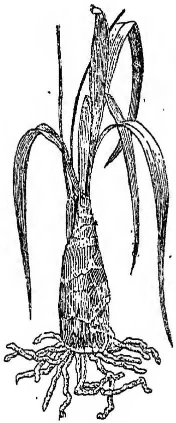


FIG. 424. *Eulophia virens*, Brown. An entire plant without inflorescence

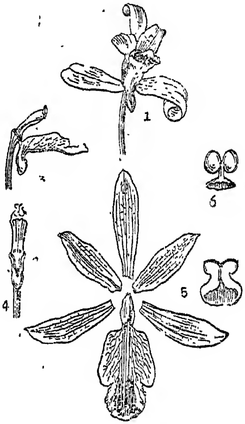


FIG. 425. *Eulophia virens*, Brown. 1, flower; 2, sepals and petals; 3, side view of lip and column; 4, front view of column; 5, anther; 6, pollinia.

Flowers are racemose on a lateral scape, and are hermaphrodite, showy and irregular; bracts are small and persistent. There are three sepals, all alike. Petals are three, but two are alike and the third is different in shape. It is three-lobed and adnate to the column and saccate at the base; the middle lobe is larger than the lateral lobes and bears inside four or five ridges of thread-like outgrowths (carinate); all the petals are green with red lines. The stamen is solitary and it is reduced to its anther, which is seated on the top of the column. The pollen grains are coherent into two oblong

masses, attached by a short strap to a discoid gland. The ovary is inferior, one-celled with three parietal placentas and the stigma is the concave face of the column below the anther. The fruit is a capsule. Seeds are extremely small with a lax hyaline testa.

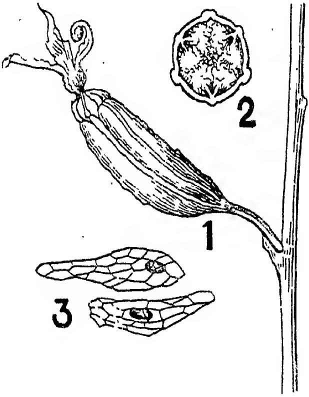


FIG. 426. *Eulophia virens*, Brown. 1, fruit; 2, transverse section of fruit; 3. seeds.

Vanda Roxburghii, R.Br., is an epiphytic orchid growing on branches of trees with long stout ærial roots. The flowers of this orchid are large and showy. The two Habenarias, *H. viridiflora*, R. Br. and *H. platyphylla*, Sprengl., occur in the plains. On the hills several species of Dendrobium, Cœlogyne, Aerides and Hebenaria are usually met with.

Characters of the Family.—The members of this family are all herbs, growing in the ground or epiphytic. Shortened and variously thickened branches are possessed by some species and these are called pseudobulbs. Flowers are usually in spikes or racemes, bisexual, irregular and often showy. Perianth is superior and consists of two whorls, the outer consisting of three sepals, more or less similar and the inner whorl of petals, more or less dissimilar; the two lateral petals are alike, but the lower petal called the lip, is variously shaped. There is a single stamen, but it is reduced to an anther united in a column with the style.

The pollen grains are coherent into waxy and powdery masses, called pollinia and these are stalked and attached by the stalk to a gland. The ovary is inferior and one-celled with parietal placentas. Fruit is a capsule and the seeds are very minute with lax hyaline testa.

This order is a very large one and the variations exhibited by the plant, especially in the structure of its flowers, are very great. However, the most striking character of all orchids is the presence of the lip and the column consisting of the combined stamen and style and the pollinia.

SCITAMINEÆ

The plantain tree, *Musa paradisiaca*, L., may be studied as a type.

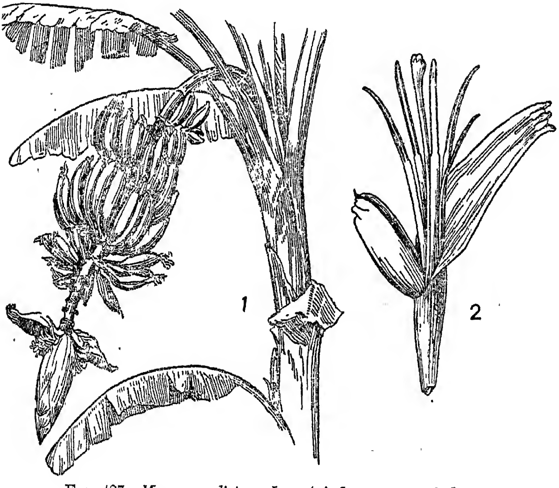


FIG. 427. *Musa paradisiaca*, L. 1, inflorescence ; 2, flower.

The so-called stem of this plant consists of leaf-sheaths. The stem is short, stout and stoloniferous. Leaves are very large, oblong, green and reaching eight feet in length and two or three feet in breadth. Flowers are in a spike which rises from the underground stem and the lower flowers are female, the middle ones bisexual and the upper male. The bracts are leathery, large, concave and spathaceous. The calyx is tubular, slit down on one side and five-toothed. The corolla is reduced to a single membranous petal. Stamens are five. The ovary is inferior, three-celled and the style is filiform and rises from a thickened base. Fruit is a berry with only imperfect seeds.

The Turmeric plant (*Curcuma longa*, L.), the Ginger plant (*Zingiber officinale*, Roscoe), the Cardamoms (*Elettaria Cardamomum*, Maton) and *Canna indica*, L., are species of this family.

Characters of the Family.—The plants of this Family are herbs, with rhizomes or stolons and the aerial stems consist, more or less, of the leaf-sheaths. Leaves are generally large, with sheathing leaf-stalks. The blade is usually large with a strong midrib and close set parallel secondary veins. Flowers are bisexual in most, though unisexual and polygamous in Musa. The perianth consists of two whorls. There are three sepals, free or connate. The petals also are three and they are free or tubular. There is only a single perfect stamen in many plants but there are five of them in Musa. Ovary is inferior, three-celled. Fruit is a berry or a capsule. Seeds are arillate (in some species) and the endosperm is floury.

AMARYLLIDEÆ

The garden plant *Crinum asiaticum*, L., is a species of this family.

This plant is a herb with a large tunicated bulb. The bulb has a long stout neck. Leaves are very long and very broad, linear lanceolate, flat and with sheathing base.

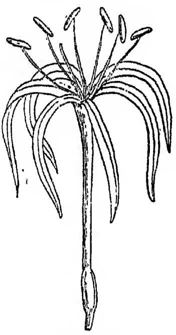


FIG. 428. A flower of *Crinum asiaticum*, L.

Flowers are large, showy and umbellate on a stout scape. Bracts are long. The perianth is tubular, white, fragrant at night, six-lobed, lobes linear-oblong. There are six stamens with versatile anthers. Ovary is inferior, three-celled, with many ovules in each.

Fruit is a capsule bursting irregularly. Seeds are few, large and rounded, with plenty of endosperm and without seed coats.

Curculigo orchioides, Gærtn., the Nilappanai, is another species very common in sandy situations. It has got a deep underground erect cylindrical stem with plicate lanceolate leaves

whose tips are sometimes viviparous. The flowers are small and bright yellow.

The agaves, *A. americana*, L., *A. vivipara, L.*, largely planted along the railway lines for hedging, are members of this family.

Polyanthes tuberosa, L., or the tuberose is largely grown in gardens throughout the Presidency. The flowers are white and are very fragrant.

Characters of the Family.—Most of he plants of this order are herbs. Stem is a bulb, or corm or an erect underground rootstock. Flowers are in umbels on a scape. Perianth is regular, biseriate, six-lobed or partite. Stamens are six, springing from the perianth lobes, and anthers versatile or erect. The ovary is inferior three-celled with many ovules. Fruit is inferior; capsular. Seeds with endosperm.

LILIACEÆ

The climbing plant *Gloriosa superba*, L., bearing large scarlet, showy flowers and found growing in dry places both on the East and West Coasts, is a good example.

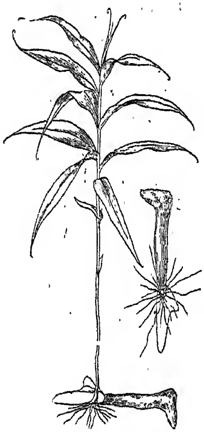


FIG. 429. *Gloriosa superba*, L.

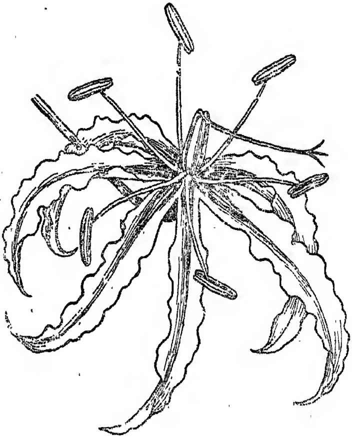


FIG. 430. A flower of *Gloriosa superba*, L.

This plant has underground stem-tubers, some of which have the shape of a country plough (hence the Tamil name Kalappai Kizhangu) and the aerial branches spring from them. (See fig. 429.) Leaves are alternate, opposite or whorled, sessile, lanceolate and the apex is modified into a tendril.

Flowers are large, solitary, axillary. There are six linear lanceolate perianth segments with wavy margins, green when young, then yellow and finally scarlet or deep orange. Stamens are six with versatile anthers. The ovary is superior, three-celled, with the style deflexed. The fruit is a capsule.

Asparagus racemosus, Willd., is a common climber with many tuberous or thickened fleshy roots, growing even in low forests. This is easily recognized by the spinous pointed cladodes, springing from the axils of minute scale-like leaves.

The Onion (*Allium Cepa*, L.) and the Garlic (*A. sativum*, L.) belong to this order.

The bulbous plants *Iphigenia indica*, A Gray, and *Scilla indica*, Baker, are fairly common in dry sandy places. *Urginea indica*, Kunth., is a common bulb met with on the sandy shores.

Chlorophytum attenuatum, Baker, and *C. tuberosum*, Baker, are met with here and there in the plains all over South India.

Characters of the Family.—Plants of this family are mostly herbs, with fibrous roots, bulb, corm, or creeping rhizome. Leaves are alternate or whorled. Flowers are bisexual, regular and the inflorescence is varied. The perianth is petaloid, usually six-lobed in two whorls. Stamens are six with long anthers. Ovary is superior three-celled. Fruit is three-celled, capsular or berried. Seeds are flattened, and with endosperm.

This order differs from Amaryllideæ in having its ovary superior instead of inferior and in other respects there is much resemblance between these two orders.

COMMELINACEÆ

The common weeds, *Cyanotis axillaris*, Schultes., and *Commelina benghalensis*, Linn., may be taken as types.

Cyanotis axillaris, Schultes., is a diffusely branching herb, with glabrous, erect and prostrate branches. Leaves are

alternate, sessile, linear or linear-lanceolate, fleshy with ciliated, inflated sheaths.

Flowers are clustered in the axils of leaves, within the inflated leaf sheaths; bracteoles are linear. There are three lanceolate sepals and the corolla is tubular with three broadly ovate lobes, violet or violet-blue. There are six perfect stamens and filaments are swollen at the apex, bearded. The ovary is three-celled with two ovules in each cell.

The fruit is a capsule, oblong, beaked and glabarous. Seeds are compressed, oblong truncate at base and with a conical tip at the apex, brown, rough and beautifully pitted.

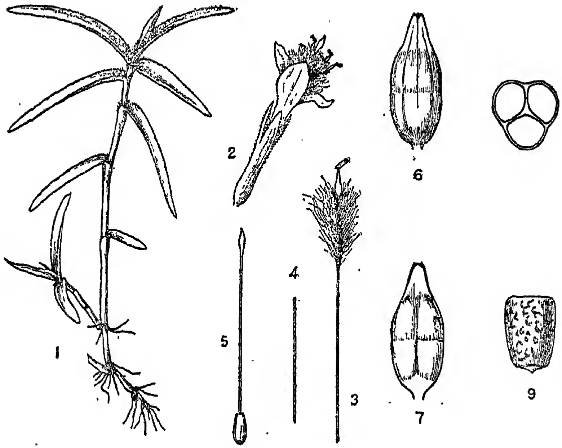


FIG. 431. *Cyanotis axillaris*, Schultes. 1, branch with roots; 2, flower; 3, stamen; 4, hair on the filament; 5, pistil; 6 and 7, fruit; 8, fruit cut across; 9, seed.

Cyanotis cucullata, Kunth., is another species met with as a weed in cultivated lands. It differs from *C. axillaris* in having almost naked filaments and a fruit broad at the apex and this plant is more robust.

Commelina benghalensis, L., is a slender, diffusely and dichotomously branching herb, with creeping and rooting branches. Leaves are alternate, oblong or ovate-oblong, sessile or short-stalked, base unequal sided, sparsely hairy on both

sides. Flowers are enclosed in spathes, funnel-shaped, and are in scorpioid cymes. Sepals are three, small, oblong. There are three blue petals. Stamens are six, three or four being perfect and the others reduced to staminodes. The ovary is superior, three-celled, with two cells two-ovuled and the third one-ovuled. The fruit is a capsule, pyriform with five seeds. Seeds oblong, closely pitted. In this plant are found cleistogamous underground flowers, which develop fruits with one or two large seeds.

Another genus Aneilema is also very well represented in South India. Species of this genus are very common in wet situations such as borders of tank beds, paddy flats and ditches. This genus has flowers in panicles without spathes. Flowers are violet or pink. The common species are *Aneilema spiratum* R. Br., and *A. nudiflorum*, R. Br.

Characters of the Family.—Plants are all herbs, mucilaginous. Leaves are usually veined distinctly, and with sheathing bases. Flowers are bisexual, in scorpioid cymes or cymose panicles; the perianth consists of the two whorls, sepals and petals, three each. Petals are clawed, two being larger than the third. Stamens are six, all are perfect or only three, the remainder being staminodes. Ovary is two or three-celled. Fruit is capsular or indehiscent. Seeds are angled and endospermic.

PALMEÆ

The Coconut palm is a tall tree with a straight stem which is thickened at base, annulate and varying in height from fifty to eighty feet. Leaves are very large with a very long petiole expanded at the base where it clasps the stem, pinnately compound; leaflets are equidistant, linear, coriaceous. Flowers are unisexual, monœcious, in a branched spike, enclosed by a large spathe. Female flowers are few large, towards the basal portions of the branches of the spike and sometimes with a male flower on each side; there are two broad bracteoles. The perianth consists of three sepals and three petals all accrescent. The ovary is superior and three-celled. The male flowers have three very short sepals and three oblong petals both being valvate. There are six stamens. Pistillode is present, but sometimes absent,

The fruit is a fibrous drupe, with a single massive seed, which consists of a huge mass of endosperm enclosing a cavity filled with a liquid (coconut milk) and a small embryo embedded in the endosperm.

The date palm, *Phoenix sylvestris*, Roxb., *Calamus Rotang*, L., *Borassus flabellifer*, L., *Areca Catechu*, L., are some of the other palms in South India.

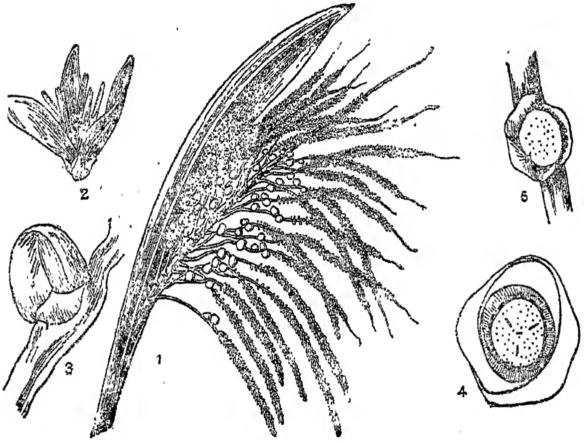


FIG. 432. *Cocos nucifera*. 1, spathe and spadix; 2, male flower; 3, female flower; 4, female flower cut across to show folding of petals and sepals; 5, bract and bracteoles at base of female flower.

Characters of the Family.—Plants of this order are shrubs or trees, with stems erect, or scandent. Leaves are alternate with sheathing petioles, plicate in bud, pinnatisect or palmate. Flowers are small, bisexual or unisexual. Sepals and petals are three each. There are usually six stamens and rarely many; filaments are free and anthers are versatile. Ovary is one to three-celled. Fruit is a drupe or a hard berry. Seeds have a small embryo and usually ruminate endosperm.

AROIDEÆ

Colocasia antiquorum, Schott., is a good example. It is a coarse herb with rhizomes and corms. Leaves are simple

with a sheathing petiole; the blade is peltate, ovate with a broad triangular sinus at the base. Flowers are unisexual, borne by a spadix which is shorter than the spathe enclosing it. The spadix has an appendage. Male flowers are above and female flowers below with neuters between. The male flower consists of only the stamens and the female of the pistil only. Fruits are berried.

This is a very well defined order in which the flowers are reduced to their essential organs, the stamens and the pistil and they are borne by a spadix enclosed by a spathe.

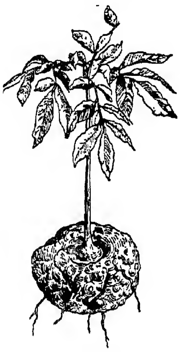


FIG. 433. *Amorphophallus campanulatus*, Bl.

The plants are perennial herbs or scandent shrubs. Leaves are alternate with a petiole having a sheathing base; blade is entire or lobed in various ways. Flowers are uni- or bisexual, monœcious. Male flowers are towards the apex of the spadix and females at the base of the spadix, often with neuters between them and sometimes with neuters above the males. Perianth is absent. Stamens in male flowers one (in bisexual more). Ovary is sessile three-celled. Fruits are berries or drupes.

Other common plants of this order are *Amorphophallus campanulatus*, Bl., *Synantherias sylvatica*, Schott., *Cryptocoryne spiralis*, Fisch., *Pistia Stratiotes*, L., *Typhonium trilobatum*, Schott., *Pothos scandens*, L., and *Theriophonum crenatum*, Bl.

Cyperus rotundus, L., a troublesome weed of cultivation is a good representative of this family.

The plant consists of many underground stolons bearing fragrant tubers and a few ærial branches terminating in inflorescences. Leaves are grass-like, three-ranked, mostly crowded at the base of the stem, with closed tubular sheaths.

Inflorescence is an umbel of spikelets. A spikelet has ten to fifty glumes distichously arranged, and the flowers are in the axils of glumes. Flowers consist of three stamens and an ovary with a three-fid stigma, and there is no perianth. The ovary is superior one-celled. The fruit is a broadly ovoid, trigonous, blackish nut.

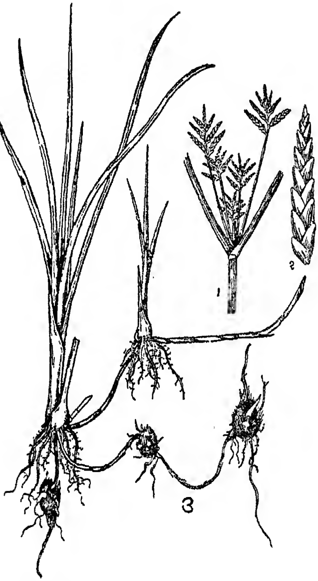


FIG. 434. *Cyperus rotundus*, L. 1, inflorescence; 2, spike; 3, stolon with tubers.

Fimbristylis miliacea, Vahl., is a common sedge of the wet lands. It is an annual with tufted stems. Leaves are shorter than the stem and their sheaths are distichously arranged. Spikelets are in compound umbels, globose, with closely imbricating ovate, boat-shaped glumes. Stamens vary from one to three. Fruit is a nut, obovoid, yellowish and tuberculate. The style is three-fid.

Characters of the Family.—The plants of this order are mostly herbs with the habit of grasses. Stem is rounded or

triquetrous. Leaves are grass-like, but the sheath is closed three ranked and without any out-growth at the junction of the blade and the leaf-sheath. Flowers are bisexual, arising from the axils of bracts (glumes), and consists of only stamens and an ovary. The perianth is absent, but sometimes as rudimentary scales, bristles, etc., because the function of protection is done by the glumes. The inflorescence consists

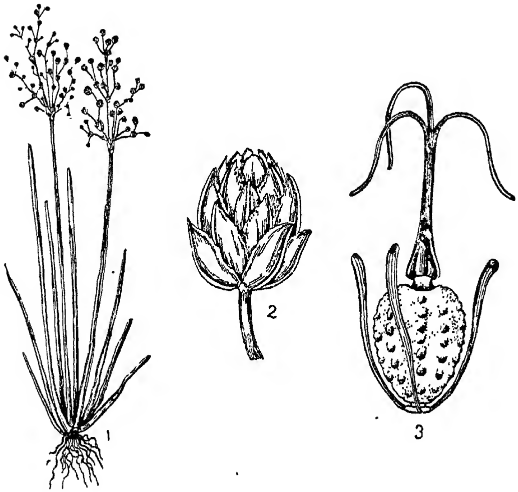


FIG 435. *Fimbristylis miliacea*, Vahl. 1, entire plant 2, spike; 3, nut with style.

of spikelets arranged in various ways. The ovary is one-celled with a solitary ovule. Fruit is a nut; triquetrous, or compressed.

Several species of Cyperus, Fimbristylis, Scirpus, Eleocharis and Fuirena occur in South India.

GRAMINEÆ

Panicum javanicum, Poir., a common grass flourishing in damp situations may be examined as a type.

It is a herb with prostrate branches, rooting below, and geniculately bending upwards. Leaves are alternate, with a loose softly hairy sheath, split open on one side; the blade

is parallel-nerved, ovate-lanceolate, acuminate and semi-amplexicaul at base. At the junction of the blade with the leaf-sheath, there is a ridge of soft hairs and this is the **ligule**, a structure peculiar to grass-leaves. The inflorescence is a panicle of spikelets. The spikelets are biseriate, ovoid with

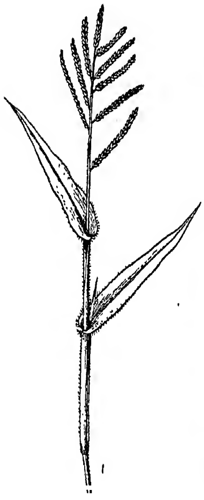


FIG. 436. *Panicum javanicum*, Poir. 1, branch.

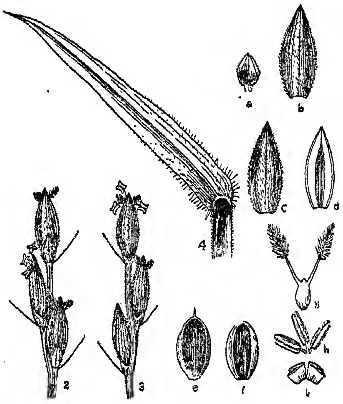


FIG. 437. *Panicum javanicum*, Poir. 2, 3, spikelets; 4, leaf blade; 5, pistil; 6, anthers; 7, lodicules, *a*, *b*, *c*, *e*, glumes; and *d* and *f*, palea.

very short, pubescent pedicels. The spikelet consists of four glumes; the first glume is very small, broadly ovate, less than half the length of the third glume, three to five-veined, the second is ovate acute, seven-veined, the third is broader, five-veined, with a palea and some times even with three stamens and the fourth is oblong rugose tip rounded and with a mucro and a crustaceous palea. Generally the first three glumes are empty, the fourth glume alone enclosing a bisexual flower. Outside the stamens and within the glume and the palea, two small cuneate fleshy bodies are seen. These are called **lodicules**, and they are considered to be the rudimentary perianth lobes. The ovary is one-celled

with two plumose stigmas. Fruit is a grain enclosed by the fourth glume and its palea.

Andropogon Sorghum, L., the cholam plant, may be studied as a second type.

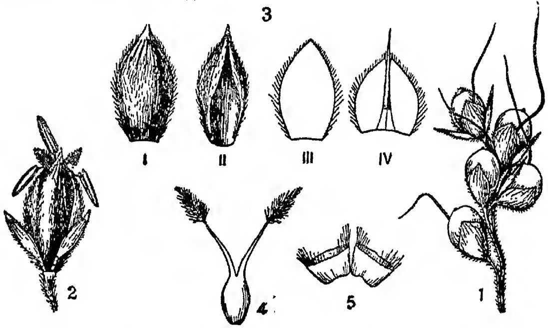


FIG. 438. *Andropogon Sorghum*, L. 1, 2, spikelets; 3, parts of the spikelet; i–iv, glumes; 4, pistil; 5, lodicules.

It is a tall plant, usually with a solid single erect stem with aerial prop roots. Leaves are alternate, bifarious and large, with a distinct hyaline ligule with a ciliated margin. The inflorescence is a mass of spikelets in a close or open panicle. There are two kinds of spikelets, the sessile and the pedicelled. The sessile one has four glumes: the first and the second are equal and somewhat coriaceous and hard, the third and the fourth glumes are thin and delicate and smaller than the second; the fourth glume is sometimes awned. Between the fourth glume and its palea there is a complete flower and the third glume is usually empty, but very rarely has in its axil three stamens. The complete flower consists of three stamens, two lodicules and an ovary with two feathery stigmas. In the pedicelled spikelets also there are four glumes and they are barren or male. The fruit is a grain.

Eleusine ægyptiaca, Desf., a common fodder grass may be taken as a third type.

It is an annual with many prostrate branches, rooting at the nodes, compressed and glabrous. Leaves are linear, glabrous or with a few hairs, and with a ligule of hairs. The inflorescence consists of four or more spikes borne palmately

at the top by a peduncle. The spikelets are biseriately arranged on one side of the axis of the spike, and each spikelet has five to seven glumes. All the glumes except the first two contain complete flowers (stamens and ovary). The floral glumes have three nerves and a two-nerved palea. There are two small cuneate lodicules. Fruit is a grain, free.

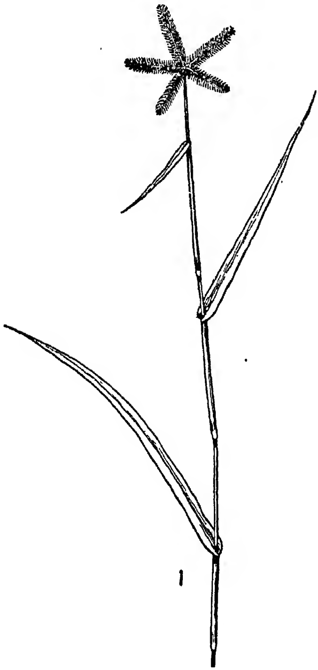


FIG. 439 *Eleusine ægyptiaca*, Desf. A branch with inflorescence.

Other Panicums met with in South India are *P. colonum*, L., *P. prostratum*, Lamk., *P. ramosum*, Linn., and *P. crus-galli*, L., and all these grow in a wild state. Some of the Panicums are also cultivated and they are *P. miliaceum*, *P. miliare* and *P. frumentaceum*.

The genera, Setaria, Andropogon, Chloris, Aristida, Eragrostis and Sporobolus are well represented in South India.

Characters of the Family.—All plants of this order are herbs, except the sugarcane and bamboo. The stem is round or compressed, hollow or solid. Leaves are alternate, two ranked, parallel-veined with a sheathing base or the leaf-sheath and a blade. The sheath is usually slit open on one side, and at the junction of the sheath with the blade, there is a ligule which is either membranous or a fringe of hairs. The flowers are reduced to the essential organs, stamens and the pistil, the perianth being represented by two very small

fleshy cuneate bodies, **the lodicules.** The bracts grow larger and afford protection to the flower and so these are called **glumes.** The flowers are sessile on the axis **(rachilla)** and are enclosed by the glumes. The glumes and the flowers are grouped into small compact spikelets and a spikelet, which may consist of four or more glumes distichously arranged, is generally taken as the unit of the inflorescence in grasses. The first two glumes of a spikelet are empty and succeeding glumes are floral glumes. The flowers arise from the axils of glumes and have on the other side a hyaline two-nerved scale called **palea.** The spikelets are in panicles, racemes, or spikes, and they are simple or compound. Stamens are usually three with slender filaments and versatile anthers. Ovary entire, one-celled, with two plumose styles. Fruit is a seed-like grain, free or adnate to the flowering glume and palea.

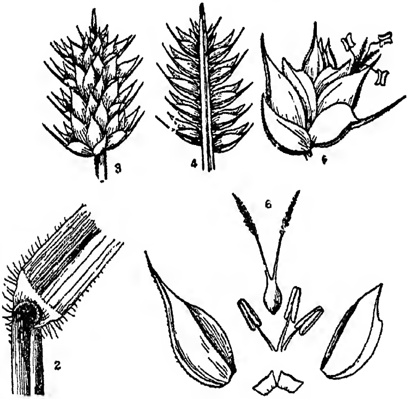


FIG. 440. *Eleusine ægyptiaca*, Desf. 2, leaf blade : 3, 4, spike; 5, spikelet; 6, flowering glume, palea, lodicules, stamens and ovary.

Of all the families this one is the largest and most widely distributed over the world. All the cereal grains, the staple foods of the mankind, Wheat, Rice, Ragi, Cholam, Millets, Maize, are members of this family. From an economic point of view this family is a most important one. Many grasses are valuable as fodder for cattle.

CHAPTER XXIII

PLANT ECOLOGY AND PLANT FORMATIONS

For systematic classification plants are viewed as separate units, and the floral characteristics form the basis for classification. The object of systematic grouping is to show the relationship and this has nothing to do with the life and habits of the plant. Plants may be viewed from a different standpoint of view, i.e., according to their environment or habitats. If we look at the vegetation of any particular locality as a whole, we find many species of plants growing together. On close examination it will also be seen that the plants belong to diverse groups having no relationship whatsoever. This intermingling of plants may be considered to be the result of accident. That it is not due to sheer chance is obvious from the fact that in similar localities we find, more or less, the same groups of plants with very slight variations, if any. Every species of plant tries its level best not only to live well, but also to increase its progeny and expand to its utmost capacity. And there will be a keen struggle amongst different species, and naturally only those species that are best fitted for the locality are likely to get established. As an ultimate result of this struggle, different species of plants, not genealogically related, may acquire similar habits and become ecological groups.

A successful living on the part of a plant indicates a harmonious relation between it and the physical factors amidst which it happens to grow. We know that a green plant is able to nourish itself, but this process is subject to the control of its environment. For the proper development and growth of a green plant oxygen, water, carbon dioxide, a certain amount of light and heat and a suitable substratum are essential. These factors act on the plant as so many stimuli and it responds readily, and it must be remembered that the response of a plant to the factors of its environment is always functional. Plants do very well so long as the intensity and amount of each of these stimuli do not rise above or fall

below certain limits. For example, in plants that receive the optimum quantity of oxygen, light, carbon dioxide and water, growth is very rapid. If, on the other hand, these factors are below the optimum, it gradually decreases and may finally even cease. Generally the maximum and minimum limits of the chief factors are not close, but far apart and, therefore, plants growing under normal conditions are able, in many cases, to prolong their lives even when these conditions have undergone modification in one direction or other; and if they possess powers of adaptation to changed conditions, they manage, at first, to live somehow, and later on they get well established. A plant that is unable to adapt itself to the most pronounced factor or factors of its environment, when such factors change, becomes extinct.

Plants growing in a particular place have to adjust themselves constantly to the various stimuli affecting them. So long as these stimuli are normal, responses on the part of the plant consist in mere normal adjustment that is necessary for their ordinary activity. For example, when the atmosphere becomes dry and at the same time somewhat hot, the leaves change their position and the stomata become closed. But as soon as these adverse conditions pass off the leaves resume their normal position and the stomata remain open. If, on the other hand, the dryness increases and the atmosphere remains dry without returning to its original conditio·, the adjustments on the part of the plant must become most pronounced and there will also be certain structural changes. So whether a plant responds by ordinary adjustment or by adjustment along with structural changes depends upon the nature of the stimulus. When the stimulus is of ordinary intensity the plant responds by its usual functional adjustments, without any change in structure, whereas on the stimulus becoming unusual in intensity or nature the response is an adaptation, i.e., adjustment coupled with some structural modifications.

In a plant it is only the vegetative organs that are affected to a marked degree, by the factors of its environment, and the reproductive organs or the parts of the flower are not at all influenced in any way. Sometimes the influence exerted by the factors is so profound as to bring about the same kind

of structural and morphological features in the vegetative organs of species of very widely separated families. For example, the three species, *Euphorbia antiquorum*, L., *Boucerosia umbellata*, W. & A., and *Opuntia Dillenii*, Haw, though belonging to three different families have the same kind of vegetative shoot. Another example of this is afforded by the species, *Limnanthemum indicum*, Thw., *Trapa bispinosa*, Roxb., *Nymphaea Lotus*, L., and *Peplidium humifusum*, Delile., belonging to four natural orders that are distant in affinity. The same kind of structural modification noticed in diverse species, genealogically wide apart, and brought into existence by ecological factors is generally termed a **growth-form.** For ecological classification, growth-forms are the units just as species form the units for the systematic grouping. The growth-forms of *Opuntia Dillenii*, *Boucerosia umbellata* and *Euphorbia antiquorum* are quite characteristic of plants growing in a dry place (Xerophytes) and the other plants mentioned are aquatics (Hydrophytes).

We always notice that certain kinds of plants live only in certain places. For example the paddy fields everywhere have certain kinds of plants and shady corners, dry hill sides, marshes and have their own distinct types of vegetation. As already remarked, these distinct types indicate a harmonious adjustment between the plants and their environment.

Ecological factors.—The chief factors affecting the plants are water, heat, light, soil, wind and associated plants and animals. These factors do not act singly. Many factors act at the same time.

The general character of the vegetation over wide areas is determined by the various factors included under climate. The factors constituting climate are rainfall, amount of sunshine, temperature, the force and direction of the winds, and all these factors depend upon the geographical position, and altitude. In places where the rainfall is well distributed and the soil is capable of good drainage plants thrive well. If in addition to these the sunshine is good there will be a profusion of vegetation. In case the rainfall is not much, although other conditions may exist, the vegetation becomes poor and stunted. The unsheltered expanses are fully exposed to the winds and consequently plants growing on such situations must

necessarily suffer. The vegetation in such situations would mostly consist of low plants, such as grasses and herbaceous plants. Trees growing in such a situation become wind swept and lopsided in growth or they become stunted and low in growth. (See figs. 441 and 442.)

FIG. 441. A wind swept tree of *Ficus glomerata*, Roxb.

The ecological factors influencing plants are not few, and their combinations are many. Therefore the number of ecological societies of plants must be large. But we shall consider some of the most striking ones, whose character depends more or less upon the factor water.

Hydrophytes or aquatic plants and their characteristics.—Of all the factors of the environment of a plant water exercises the greatest influence on plants. How very far

reaching this influence is, becomes obvious, when we compare a submerged water plant with a land plant. An aquatic like *Vallisneria spiralis*, L., or *Hydrilla verticillata*, Casp., or *Ceratophyllum demersum*, L., is very limp and delicate and so, incapable of remaining erect when taken out of water. This flaccidity is due to want of xylem and other hard tissues, so common in land plants. All submerged plants are, more or less, alike in several respects, and this is due

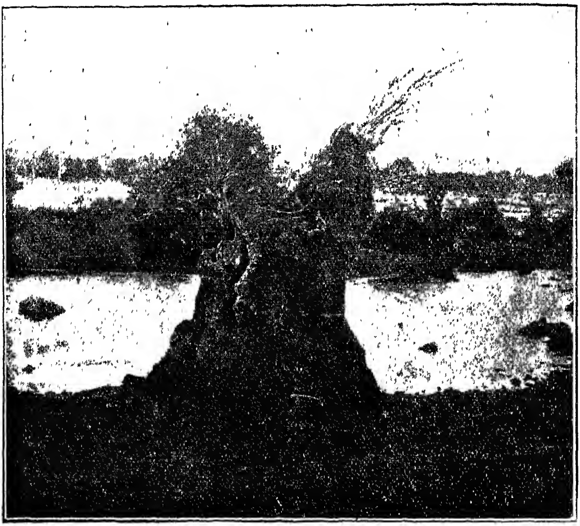


FIG. 442. A weather beaten tree of *Terminalia Arjuna*, W. & A.

to the fact that the conditions of living are more uniform under water than in air. Another characteristic feature of water plants is the possession of large air spaces in abundance. Both these characteristics, viz., the presence of air cavities and the absence of xylem tissue lead to the lessening of the specific gravity of the plant. Further, water being denser than air, by itself it will support the weight of the plant.

A land plant gets mineral salts from the water contained in the soil and the gases from the atmosphere, whereas a

submerged plant depends for everything on water. Consequently the absorbing organs, roots and root hairs and the conducting tissue or xylem, so essential for a land plant, become superfluous in the case of aquatics. However, where roots and root-hairs are present, they are helpful in fixing the plant to its substratum. As water plants are not subjected to the strains due to wind and weight to which the shoots of land plants are exposed, the need for mechanical tissue does not exist, and the required support is afforded by water in a thorough manner. However, like roots, the shoot systems of aquatics are subjected to longitudinal strain caused by movement of water, and to resist this longitudinal pull, the few xylem elements present in the stem are found arranged axially, i.e., as near to the centre of the stem as possible.

The air spaces in water plants, besides helping them to float, facilitate, the process of respiration. A submerged plant is unable to get oxygen as readily and as easily as a land plant, because water does not absorb oxygen in large quantities. The air spaces convey oxygen to all parts that are submerged. In the case of plants growing in salt swamps and marshes oxygen cannot be obtained with ease, because water absorbs only a limited quantity of oxygen. To overcome this difficulty, plants growing in salt swamps have breathing roots or pneumatophores. In marsh plants a special tissue called ærenchyma is formed from the phellogen layer either in the roots as in the case of *Jussiaea suffruticosa* and Sesbania, or in the stem as in *Neptunia oleracea*, etc. Some free, floating plants growing in stagnant water and marshes, have leaves with finely divided blades and this leads to the increase in the absorbing surface.

A submerged water plant is able to absorb water through all its parts. The epidermis needs no cutin and stomata are also unnecessary. As light passes through water on all sides the leaves are, like shade leaves, without any distinction into palisade and spongy parenchyma. The epidermis also contains chloroplastids.

The aquatic mode of life is highly advantageous for rapid growth, because water can absorb large quantities of carbon dioxide, and plenty of water, salts and oxygen also are available for the plant. Thus favoured, these plants grow

rapidly, multiply and extend very quickly, by means of vegetative reproduction.

It is a well-known fact that humidity and abundance of food material always tend to favour the growth of vegetative organs and prevent the formation of sexual organs, whereas dryness favours the formation of sexual organs. So in water plants vegetative multiplication far exceeds the sexual reproduction, and some species such as Elodea and Lemna multiply solely by vegetative propagation. In cases where flowers are produced, as in *Vallisneria spiralis* and *Hydrilla verticillata*, special adaptations exist to bring about pollination. The female flowers are borne on long stalks and so they come up to the surface of the water to get pollinated. Male flowers get detached and float in large numbers, which must necessarily bring about pollination.

A great majority of water plants are submerged plants. Of these some are free swimming and others fixed to the substratum. Most of the species of the order Hydrocharideæ are aquatics fixed to the soil and plants like Ceratophyllum and Utricularia, float and are carried about freely in water.

The leaves of aquatics that are submerged are delicate and thin, and they show considerable amount of variation. Plants, growing in situations where water is always still without disturbance, have large leaves (e.g., *Ottelia alismoides*). The leaves of plants subjected to movements of water have either ribbon shaped leaves (e.g., Vallisneria) or their leaf blades are divided into small linear segments (e.g., Ceratophyllum and Utricularia).

There are also some aquatics whose leaves always float on the surface of the water, as in Nymphæa, Aponogeton and Limnanthemum. The leaves are in this case thick with continuous margin and plenty of cuticle or wax on the upper side. Large number of stomata are also found on the upper surface.

Lastly we have a large number of plants growing in marshes and edges of ponds and tanks. In all these plants, a portion of the shoot system is submerged and the remaining portion is ærial. Leaves that are submerged differ very much from the ærial leaves (e.g., several species of Limnophila),

The possession of ærial leaves enables these marsh plants to grow even in stagnant pools and ditches.

Xerophytes or plants of dry regions.—Ordinary land plants depend upon the soil for their water, and they do well so long as there is an adequate supply. When a plant gets a liberal and uniform supply of water it produces leaves with large thin blades, softer less woody parts and very few protective appliances. Plants growing in thick moist forests are of this kind. In all tropical forests with a heavy rainfall, great luxuriance of vegetation is the prevailing condition. If water becomes scarce in a tropical region, the vegetation suffers very much and it becomes stunted.

FIG. 443. *Canthium parviflorum*, Lamk., growing in a scrub jungle.

The organization of a land plant is such as to ensure a regular flow of a rapid current of water from the roots to the leaves and constant transpiration from the leaf surface. The structure, position and arrangement of leaves are intended to facilitate transpiration. If, for any reason, the roots are

unable to absorb water freely, the plant will suffer unless the transpiration that may be going on is prevented. In moderately dry places, as a rule, the plants manage to lower the transpiration by various means. If the period of drought is not long, there will not be very great change in the plant, beyond mere adjustment. On the other hand, plants growing in places where there is a prolonged drought get modified in various directions, and although of widely different families they all become remarkably similar, and we get definite growth-forms.

The xerophilous plants present three types of growth-forms in South India. Many xerophytes have deep roots and when water becomes scarce in the upper layers, they go deeper still to obtain water from the underlying moist layers. At best it can only absorb small quantities of water, and this has to go to the leaf rapidly without much loss. Hence the stem is woody with very narrow cortex.

At the same time the loss of water taking place in the ærial part of the plant on account of transpiration should be minimised. So the leaves become smaller and fewer in number, the cutin of the epidermis becomes very thick and the stomata decrease in number, and instead of being flush with the epidermis lie deep in furrows. Cork layers are also formed in the stem. As an example for this we may mention *Indigofera trita*. Other plants of a similar nature are *Desmodium biarticulatum*, *Indigofera aspalathoides*, *Justicia tranquebariensis* and *Stylosanthes mucronata*.

Another class of xerophytes is the one typified by Boucerosia or the Prickly-pear. Plants of this sort have only fibrous roots and so they are able to take in water, available in the upper layers of the soil. When the soil is somewhat moist these plants absorb water greedily and store it inside the plant in special parenchyma called water-tissue. As transpiration has to be reduced to its minimum, leaves are not formed and even when formed they are minute and drop off after some time. The stem becomes fleshy on account of the water storage tissue and to prevent the loss of water the epidermis of the stem gets a thick coating of cutin and the stomata are greatly reduced in number and they lie deep in furrows.

Another type of xerophyte is the one in which the leaves become fleshy and thick, as in Agaves and Aloes. The leaf instead of the stem becomes the store-house for water. All the arrangements that usually check transpiration are developed and the leaves are close set. In both the types represented by Agave and Boucerosia, the plants have the water stored in them thickened by mucilage, another device to check undue evaporation.

Although the modifications in xerophytes are very varied, yet they all have the same purpose, viz., the prevention of loss of water by excessive transpiration. Leaves being the organs most concerned in this work they are the first to be affected under unfavourable conditions. There are all gradations between a normal land plant growing in shade and a pronounced xerophyte.

Halophytes or **plants of saline soil.**—The xerophytic growth-forms already mentioned are evoked by a dry soil. Roots of these plants are unable to absorb water in large quantities because of the scarcity of water. There are a number of plants whose roots do not absorb water freely, although it may exist in abundance. Plants flourishing in salt swamps and saline soils take in water very slowly and sparingly, otherwise the salt in the water will poison the plants and ultimately lead to their death.

Halophytes present a great similarity in habit and other respects to the xerophytes, and in this group we have another example of plants of distant affinities, in which the environment evokes similar characteristics, so that they may become adapted for their surroundings. Ordinary xerophytes of the dry regions suffer from physical drought and halophytes are subjected to physiological drought. In both the cases the effect of the environment on the plant-body is similar. So halophytes constitute one form of xerophytes.

As salt water acts lethally on the plants when freely absorbed, halophytes are obliged to take water in small quantities. Arrangement for the reduction of transpiration is also an absolute necessity in the case of these plants.

In South India on both the East and West Coasts we have salt swamps and saline flats. The land in close proximity to the sea and at the mouths of rivers in backwaters, get

submerged daily by the tide and will be exposed only at low water. The soil in these situations consists of clay or clay and sand saturated with water and reeking with foul odour on account of decaying organic matter. There will be no air in this mud. Even such a soil supports vegetation of a particular type, which is called "mangrove formation." This type of vegetation is very interesting in some respects. Most of the plants are low trees or shrubs with their trunks and branches supported by numerous, crooked, irregular prop roots, as if on stilts. These prop roots are spongy in structure and are full of air spaces. Some roots have large lenticels and other arrangements to facilitate the absorption of air. Some species of plants, like *Avicennia officinalis* and *Sonneratia acida* have special respiratory roots, which stand out erect above the ground in rows all around the trees. As the absorption of water is slow, transpiration must of necessity be checked very much. So the leaves of mangrove trees are usually thick, succulent with close set several layered parenchyma and also with water storing cells in some species. The seeds of mangrove it allowed to fall in the mud will never germinate. So in these plants seeds germinate, while the fruit is still attached to the plant. The embryo plant goes on absorbing food material from the parent plant until it develops into a large seedling. The seedling in many species consists of a long club-shaped radicle with lateral roots and a hypocotyl with a short shoot. These seedlings look very much like long pods. When fully formed they drop off and the club-shape and the pointed end enable them to pierce the mud. Or if they happen to fall on water, they float and get stuck in holes at the earliest opportunity.

As we recede from the mangrove formation we find number of other species of plants. In nooks and corners and in wet places near the backwaters the herb *Acanthus ilicifolius* grows in abundance. Here and there we find Pandanus lifting its head from amidst Acanthus. Further away in flats that are distinctly saline we meet with several species of Suædas and Salicornias, *Sesuvium Portulacastrum* and in some places Tamarix also. All these plants are either herbs or shrubs, with pronounced xerophytic features. The flora supported by the dry sand of the sea-shore is

striking although it may merge into the ordinary scrub flora towards the inland. The creeping plants *Cyperus arenarius*, *Spinifex squarrosus*, *Lippia nodiflora*, *Ipomoea biloba*, *Launaea pinnatifida* are abundant though they lie scattered. On the West Coast we have also some trees and shrubs growing in such situations, such as *Barringtonia racemosa*, *Hibiscus tiliaceus* and Excœcarias.

FIG. 444 *Spinifex squarrosus* formation.

Epiphytes are a group of plants living under very peculiar conditions. They attach themselves to other plants by means of aerial roots, but without abstracting anything from the latter. On account of this unusual position, obtaining food and water must be a matter of very great difficulty. But they have managed to overcome this difficulty in a variety of ways. For example, many of the epiphytic orchids and aroids growing in South India possess aerial roots specially adapted for the absorption of water. These aerial roots are white in appearance owing to the formation of a kind of sheath consisting of several layers of empty cells strengthened with thickenings here and there. This sheath is called

velamen and it acts as a sort of sponge in absorbing water rapidly, whenever there is rain.

As the sources of supply of water for epiphytes are dew, mist or rain, it is evident that they can at best have only a precarious supply at long or short intervals. Therefore we should expect these plants not only to be very sparing in the use of water but also to have arrangements for the storage of water.

FIG. 445. *Spinifex s*

The epiphytes also, like land xerophytes, have to endure prolonged droughts and consequently they have many structural features in common. And these structural features are those of pronounced xerophytes.

From what was said above, it is clear that epiphytes cannot live in places where the climate is very dry; but they can live where the atmosphere is likely to be humid at least for some months. On the East Coast of South India we do not find many epiphytes, but, on the other hand, on the West Coast they are abundant. The frontispiece shows a photograph of

a Peepul tree abounding in the epiphytes, *Vanda Roxburghii* and *Drynaria quercifolia.*

Mesophytes are the ordinary average plants thriving in a soil of moderate humidity and they avoid the soil with standing water or water containing a high percentage of salts. These plants occupy an intermediate position between the xerophytes, on the one hand and the hydrophytes on the other, and are abundant in regions where the rainfall is evenly distributed.

In the previous chapters of this book we have been dealing with the structure and function of seed plants, and most of it has reference only to the mesophytes. The leaves of these plants are specially adapted for rapid transpiration and so they are usually large and far more varied in form than xerophytes. The special tissues such as ærenchyma or water storage-tissue are not usually found in these plants. All the plants that abound in the forests of the hills of South India consist mostly of mesophytes.

The vegetation of this Presidency is most interesting as we find in it all kinds of formations. On the sea coast we have the mangrove and salt loving plants. This is succeeded by the sand binding xerophytic plants such as Spinifex, Ipomœa biloba, etc., and this gradually merges into the scrub jungle. The vegetation on the Deccan portion consists of scrubby jungles, and deciduous forests. All the thick evergreen forests are confined to the higher hills and the Western ghats.

CHAPTER XXIV

CRYPTOGAMS—PTERIDOPHYTA

CRYPTOGAMS

BESIDES the seed plants with which we have been dealing so far, there are a host of plants that do not produce seeds. All such plants are included under the class **Cryptogams**, under the belief that the sexual reproduction in these plants is hidden. Later on it will become obvious that the sexual reproduction taking place in both Phanerogams and Cryptogams is similar in all essential respects. However, with a view to avoid confusion, the term Cryptogam is still retained, in spite of its being inappropriate.

There is a fundamental difference between Spermatophytes and Cryptogams in the mode of their propagation. In flowering plants propagation is effected by means of **seed**, whilst cryptogams carry on the work of propagation by means of special bodies called **spores**. **Seeds** are multicellular bodies containing within them the embryo or the rudiment of a plant, which is also a multicellular body. On the other hand, the **spores** are unicellular bodies giving rise to independent new plants which are either unicellular or multicellular, according to the kind of the plant. Seed plants also produce spores, it is true, but those spores do not give rise to new individuals directly. The pollen grains and the ovules are really spores.

Like Phanerogams, Cryptogams also consist of an extraordinary variety of plant forms, ranging from unicellular organisms to plants exhibiting differentiations into distinct organs, such as leaves, stems and roots.

The Cryptogams consist of the three distinct groups of plants Thallophyta, Bryophyta and Pteridophyta.

The **Thallophyta** is the lowest group. Plants of this group consist of cells only, without any differentiation into tissues. In other words the plant body or the **thallus** is simply a mass of cells, all more or less alike.

The **Bryophyta** or mosses and liverworts are somewhat higher than the thallophyta and have a slight differentiation

in their plant body, into stem and leaf, at least in the higher forms.

The **Pteridophyta** are the most highly organized plants amongst the cryptogams. They have their bodies differentiated into roots, stems and leaves. As the leaves, stems and roots of these plants have tissue differentiations which are similar to those found in the stems, leaves and roots of spermatophytes, these are sometimes called **Vascular Cryptogams.**

PTERIDOPHYTA

Plants included in this group differ very much, ranging from very small, lowly plants to those as high as a man and up to thirty feet in the case of tree-ferns. There are also differences in other respects. So it is necessary to take as examples four distinct plants to represent the main types. We shall take as examples *Adiantum Capillus-veneris* (the maiden-hair fern), *Marsilia minuta* (the water fern), *Lycopodium cernuum* (the club moss) and *Selaginella plumosa* (the little or delicate club moss).

The Maiden-hair fern or **Adiantum.**—By far the most important group amongst Pteridophyta is undoubtedly the class Filices or true ferns. The common maiden-hair fern, *Adiantum Capillus-veneris*, found in all gardens and conservatories is a typical example of the ferns proper. In this plant there is a well-marked differentiation into stem, roots which are underground and leaves which alone are aerial.

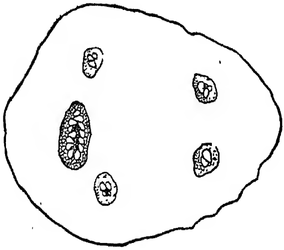
The underground stem or rhizome is perennial, and as it elongates and pushes through the soil horizontally, leaves arise from the upper and roots from the lower surface. The whole of the rhizome is covered by thin scale like structures called **ramenta.** Elongation of the horizontal rhizome is due to the growth of the apical bud which consists of the growing point and a rosette of young leaves all densely clothed with ramenta. Branching of the rhizome is never so frequent or profuse as in the shoots of flowering plants. Occasionally adventitious buds arise and these develop into lateral branches. The apical growing point may sometimes become bifurcated and then two branches will be formed. Axillary buds, so characteristic of the flowering plants, are not formed in this and other ferns.

By far the most attractive part of ferns in general, and of the maiden-hair fern in particular, is the leaf. The leaf is a large one and it is very much divided, and it is called a **frond**. The main petiole and its branches are black and shining. The leaflets or pinnules are green and cuneiform. The venation of the leaflet is also very striking and quite characteristic of most of the ferns. The veins branch regularly and dichotomously. Another special feature is the circinnate folding of the leaf when it is young. The growth of the fronds of ferns is very slow, and usually only one leaf develops into a mature leaf in one season. (See fig. 446.)

FIG. 446. *Adiantum Capillus-veneris.* 1, full plant; 2, the apical portion of the rhizome.

Roots of the maiden-hair fern, as well as those of most ferns, are adventitious, and they resemble the roots of the seed-plants in every way.

The stem is woody and consists of tissues usually found in seed plants. A transverse section of the stem shows a cortex, a vascular cylinder and pith, but the vascular bundles differ from those found in flowering plants, both in arrangement of the parts and in its elements. The xylem is surrounded by the phloëm in the vascular bundles of the elements are tracheids formed of single cells and not vessels resulting from fusion of cells. There is no cambium. (See figs. 447 and 448.)



IG. 447. Transverse section of t rhizome of the maiden-hair fern.

The growing point of the stem has at its apex a single large cell instead of a group of small cells.

The internal structure of the leaflet is not very different from that of the bifacial type of leaf of phanerogams. In the fern leaflet, there is the same differentiation of chlorenchyma into spongy and palisade parenchyma with the epidermis covering the leaf-surface on both the sides. Stomata are most numerous in the lower epidermis.

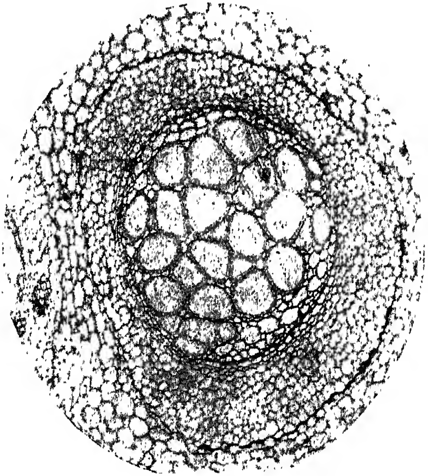


FIG. 448. Transverse section of a vascular bundle in the rhizome of a fern highly magnified.

The Sporangia.—The edges of pinnules of mature fronds look as if folded under. At first these folds are not conspicuous but they become prominent later on. If these flaps are lifted brown spots are seen on the lower side of these flaps. These spots are really groups of sporangia, and they are called **sori**. Each **sorus** consists of a number of sporangia in different stages of development. The sori are connected with the ends of the veins.

A ripe sporangium consists of a short stalk and a somewhat rounded spore-case or capsule borne by the stalk. The spore-case contains many small spores. The spore-case is lens-shaped when viewed on its profile, and it consists of one

layer of thin-walled cells on the sides and a ring of thick-walled cells called **annulus**, running up from the top of the stalk on one side over the top to about the middle of the other side. The cells lying between the end of the annulus and the top of the stalk on this side are thin-walled cells and hence the weakest point is there. In each of the cells of the annulus the inner wall and the radial walls are thickened, whilst the outer and side walls remain thin. (See figs. 449 and 450.)

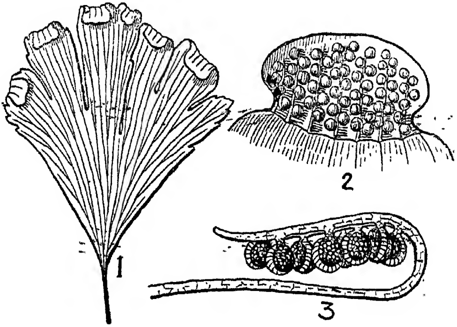


FIG. 449. *Adiantum Capillus-veneris.* 1, a pinnule; 2, flap turned over to show the sori; 3, section through the flap showing the sporangia.

The bursting of the sporangium when it is ripe is due to the peculiar behaviour of the annulus. So long as the sporangium is young, all the cells contain water and they will all be turgid. But as it matures the amount of water begins to decrease in all the cells. By the diminution of water the cells of the annulus will be affected. In consequence of the escape of water the thin walls of the annulus begin to shrink and pull the radial walls close

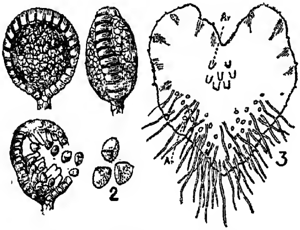


FIG. 450. *Adiantum Capillus-veneris.* 1, sporangia; 2, spores; 3, prothallus. An, antheridia; Ar, archegonia.

together in every cell. If all the cells are subjected to this shrinkage and pulling together of the thickened wall, the annulus must tend to shorten as a whole and this must necessarily cause the splitting of the capsule at the weakest point. As the lateral portions of the capsule consist of thin-walled cells, the splitting will extend from the weakest point to its lateral membranes. Then the annulus, becomes almost straight, when the tension becomes still less, carrying with it the upper portion of the capsule with a considerable number of spores. . Gradually the cells of the annulus get filled with air and finally the annulus returns to its original position with a quick jerk. This very rapid-snapping back to its former position throws out the spores to a considerable distance.

If sections of the pinnules across the flaps are examined sporangia in various stages of development may be seen and they would be found to be connected with the prolongations of the veins. (See fig. 449.) When very young the sporangium consists of a mass of cells all similar. As development progresses changes take place in the mass of cells within the capsule. A mass of cells becomes differentiated into spore mother cells in the centre and these are surrounded by layers of cells which function as nutritive cells. Gradually the nutritive cells are absorbed, and the capsule will ultimately consist of the wall of the capsule and the spore mother cells within. Each spore mother cell becomes divided into four free spores. When the sporangium is mature, the spores lie loosely within the capsule and the annulus would be well differentiated and developed. The formation of spore mother cells and their further development are exactly similar to the formation of pollen mother cells and pollen grains in the pollen sacs of anthers. As a matter of fact, the pollen grains are really spores.

Gametophyte or the **Prothallus.**—The spores of this fern, as well as of other ferns, are very small and light, and consequently capable of floating in the atmosphere like dust. When spores are sown on moist earth, or on brick, or pieces of tile standing in water, and kept in moist air, they germinate and form small green, thin bodies called prothallia. The prothallus when fully formed is somewhat rounded

with a broad and deep depression in the front. It becomes fixed to the soil or substratum by means of long delicate unicellular prolongations called **rhizoids**. As a rule this prothallus is one cell thick, except in the middle which is somewhat thicker and consists of more than one layer of cells. This thickened part is called the cushion.

The prothallia bear on their lower surfaces two sets of organs called **antheridia** and **archegonia**. The antheridia are usually found towards the base of the prothallus amidst the rhizoids. They are small outgrowths consisting of a mass of cells enclosed by a wall of one layer of dome-shaped cells. The central mass of cells develops into **antherazooids** or **sperm-cells**. When the antherid is mature, its wall bursts at the top, setting free the spirally-coiled sperm-cells, provided with many cilia. These sperm-cells move about freely in water.

The archegonia are found somewhat close to the depression in front of the prothallus, and a little to the front of the antheridia. Each archegonium consists of a short neck bent over and away from the growing point and a flask-shaped portion or venter immersed in the body of the prothallus. It is the neck alone that protrudes and projects beyond the surface of the prothallus. The neck has a canal leading into the venter in which the egg-cell lies.

The sperm-cells are attracted to the mouth of the archegonia by the mallic acid in the mucilaginous substance present in the neck-canal. They are caught in the viscid substance lying at the broad open mouth of the neck of the archegonium. Working its way through the neck-canal the sperm-cell reaches the egg-cell and fuses with it. The single cell resulting from the fusion of the egg-cell and the sperm-cell begins to divide repeatedly and finally developes into the ordinary fern plant.

The life-history of a Fern.—The life history of the maiden-hair fern or other true ferns is very interesting. The ordinary fern plant is the one which produces the spores and hence it is called the **spore-bearing plant** or the **sporophyte**. From the spores prothallia develop and on the prothallia appear two kinds of organs producing the sexual cells called the egg-cell and the sperm-cell. The

fusion of the sperm-cell with the egg-cell is the sexual reproduction. So the prothallus is an individual plant leading an independent life and containing the sexual organs. It is for this reason that this is called the **gametophyte** or the **sexual plant.**

Thus it is seen that in the case of a fern plant there are two generations of plants, one coming after the other in regular alternation. The sexual generation is a very small inconspicuous plant, whereas the spore bearing plant is a large one. This alternation of generations occurs in almost all Pteridophyta.

Ferns are found growing in astonishing profusion and variety upon moist rocks, trunks of trees, as well as upon the earth in mountainous districts where the rainfall is high. Being shade-loving plants they are usually confined to shady banks, nooks and crannies, where there is an accumulation of humus soil. In habit the ferns vary very much. They are erect or creeping, some form thickets and others are climbers.

Marsilia or Water-Fern

The common aquatic or marsh weed *Marsilia minuta*, L., is a fern, although at first sight it does not look like a fern. It has a horizontal creeping stem bearing leaves above and roots below. The free growing tip has an apical cell which gives rise to three or four rows of cells by repeated division.

The leaves are circinnately folded when young, as in the case of ordinary ferns and they have long stalks bearing peltately four cuneate leaflets.

As in Adiantum spores are formed in Marsilia also within the sporangia. But the spores are of two kinds, one small and the other very much larger. The small spores or **microspores** as well as the larger or **megaspores** are formed within sporangia. Those sporangia that contain megaspores are termed **megasporangia** and those with microspores, **microsporangia.** The sporangia are collected together in sori, each sorus having a few megasporangia and a number of microsporangia. There are usually a number of sori arranged on the two sides within a bean-shaped body called sporocarp. Sporocarps are very hard bodies and

when mature they split and from within a mucilaginous ring comes out bearing on it a large number of sori consisting of both megasporangia and microsporangia. (See figs. 452 and 453.)

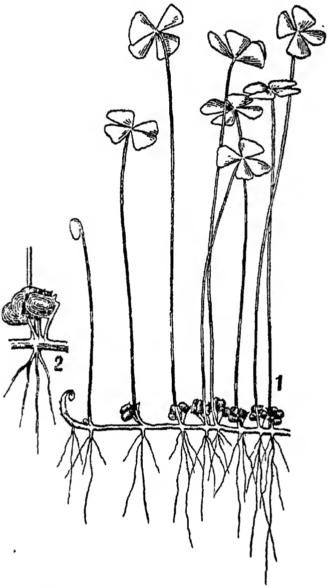


FIG. 451. *Marsilia minuta*, L. 1, full plant; 2, sporocarps.

These bodies are very hardy and they are said to retain their vitality for a very long time. It is said that sporocarps found on herbarium sheets or kept in spirit will often begin to show activity.

The drawing in fig. 453 was made from a sporocarp collected in 1915 by Professor Chamberlain. A few sporocarps were given to me by Dr. Sampathkumaran of Bangalore. They were put in water and the gelatinous stalk was out in fifteen minutes.

The microspore germinates, but the male gametophyte does not come out of the spore. As a matter of fact the gametophyte is extremely small, consisting of only one

vegetative cell and a single antheridium which gives rise to a number of sperm-cells or antherozoids. Each antherozoid is a spirally coiled body with cilia on the lower coils and

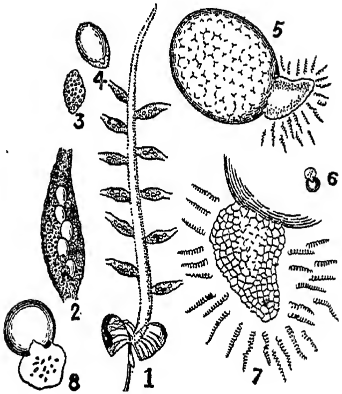


FIG. 452. *Marsilia minuta*, L. 1, sporocarp burst open and with sori on a gelatinous stalk; 2, sorus; 3, microsporangium; 4, megasporangium; 5 and 7, germinating megaspores, showing the prothallus and the sperm cells; 6 and 8, germinating microspores.

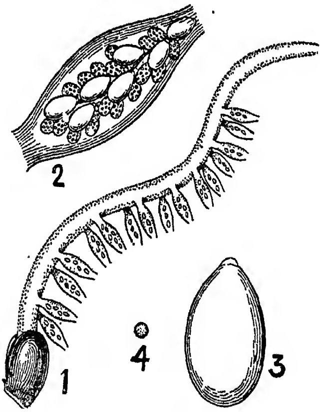


FIG. 453. *Marsilia*, Sp. 1, sporocarp burst open and with sori on a gelatinous stalk; 2, sorus; 3, megaspore; 4, microspore.

having none on the upper. The female gametophyte or prothallium is also very much reduced and it does not emerge from the megaspore. Within the spore is found a large cell serving as a nutritive cell and on the top of it is developed a single archegonium. (See figs. 450 and 451.)

The internal structure of the leaves, stems and roots is more or less similar to that of the leaves, stems and roots of ferns.

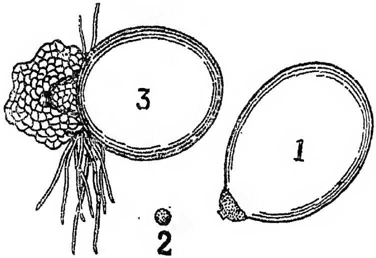


FIG. 454. *Marsilia minuta*, L. 1, megaspore; 2, microspore; 3, megaspore after ferilisation and with embryo formed in it.

The most striking feature of this water fern is the possession of the two kinds of spores, megaspores and microspores (heterospory), which are enclosed in megasporangia and microsporangia respectively. Further these sporangia are in rows of sori and these are enclosed in sporocarps. The sporocarps usually arise from the base of the leaves.

Besides the species *Marsilia minuta*, which is of very wide distribution, there is another one *M. Coromandelica* which is also of common occurrence. This can be recognized by the larger leaves having no toothed margins.

LYCOPODIUM OR CLUB MOSS.

Lycopodium cernuum may be studied as a type of this group. This plant has a prostrate stem running for considerable distance either just on the surface amidst rotting leaves and humus or beneath the soil. Numerous secondary branches arise and all of them are closely covered by a large number of small leaves. Some of these branches bear at their free ends somewhat club-shaped bodies, called cones,

A cone consists of an axis with close set small leaves, which are, however, slightly larger than those on the axis below.

In the axils of all the leaves of a cone sporangia are found, but not in the axils of leaves in other parts of the stem. Since the leaves of the cone have sporangia, they are called **sporophylls** or spore-bearing leaves. In this plant the leaves are thus differentiated into sporophyll and ordinary foliage sterile leaves. There are a few species of Lycopodium in which all the leaves have sporangia in their axils without any differentiation.

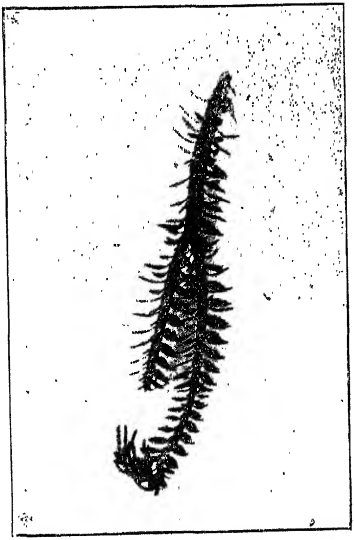


FIG. 455. Lycopodium.

The spores in the sporangia are all of the same kind and hence this plant is called **homosporous**. The spores are so small and so abundant that they form a fine powder which is of some commercial importance. This lycopodium powder is used in coating pills and in pyrotechnics. The spore gives rise to a prothallus which is usually tuberous and underground. Ordinarily the prothallus is perennial and in

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some species, it remains entirely underground whilst in others an aerial lobed portion usually greenish in colour is formed on the top of the tuberous part. Antheridia and archegonia are formed in this lobed aerial portion or in the underground portion when no aerial portion is formed.

SELAGINELLA OR LITTLE CLUB-MOSS

Selaginellas are met with in the plains on the West Coast, and on the hills they form a most attractive feature of the forest vegetation. They are grown in gardens on account of their beauty and for their decorative effect.

We may choose for study *Selaginella plumosa*, a species fairly common in South India. If this is difficult to obtain,

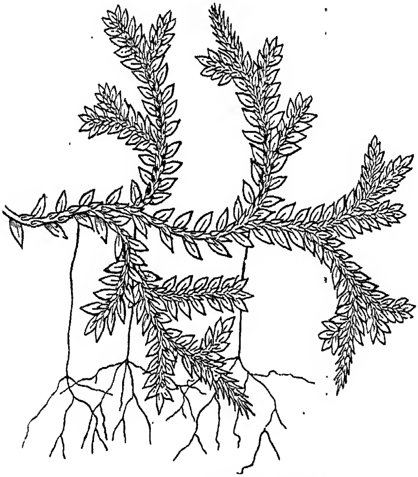


FIG. 456. *Selaginella plumosa*.

Selaginella inequalifolia which is largely cultivated in the conservatories and gardens may be substituted. This plant is a delicate one with a creeping habit. The stem branches freely and the branches are covered with many small leaves arranged in four rows of two sizes. Two rows of larger leaves are below and two rows of smaller leaves are above.

The stem branches dichotomously at intervals more or less unequally, and the branching is never axillary as is the case in flowering plants. From below the stem where it forks springs a naked greenish or white root-like structure called the **rhizophore**, and this on reaching the soil developes roots at its free end. (See fig. 456.)

In fully grown plants at the extremities of some of the branches are found cones. In the cones the leaves are all alike and they are arranged evenly round the axis overlapping one another.

In the axils of the leaves of a cone sporangia are found. In the axils of the leaves towards the upper portion of the cone microsporangia are found. These contain a large number of microspores which are liberated by a slit across the top of the sporangium. The sporangia borne by the few leaves at the base of the cone in their axils are megasporangia containing four megaspores in each.

The megaspores are large and they have very thick walls and with reticulations. On one side of this spore three radiating ridges are visible, and it is here that the spore bursts open. At first though large, the spore consists of only a single cell and as the spore matures it divides and a

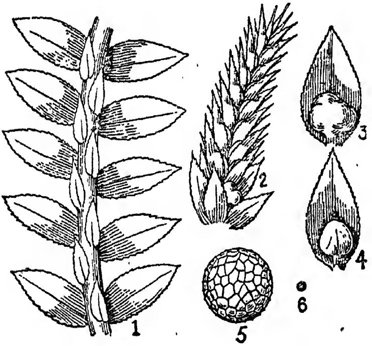


FIG. 457. *Selaginella plumosa.* 1, a portion of a branch; 2, the portion of the branch bearing sporangia; 3, megasporangium; 4, microsporangium; 5, megaspore; 6, microspore.

comes into existence. When a spore falls on a suitable place it bursts where the thick radiating lines meet, and the tissue inside grows out through the opening to a certain extent,

without protruding very much. It is on this part that archegonia arise.

The microspores consist of a few cells and most of them except a few peripheral ones become changed into anthero-zoids, which are biciliated slightly curved bodies. After fertilization the oosperm developes into an embryo and then this develops into a seedling. In Selaginella also there are two stages of the plant, and there is the regular alternation of generations as in the case of the Ferns. But this plant is heterosporous and the prothallium is unisexual, and it never leaves the spore.

All Pteridophytes have an independent sporophyte or spore-bearing plant with well developed stems, leaves and roots. In all its parts there is differentiation of tissues into different kinds usually found in seed plants. Amongst leaves, most of them are sterile foliage leaves and a few become changed into sporophylls or spore-bearing leaves. In some plants the sporophylls do not materially differ from the sterile leaves, whilst in others they look different and are aggregated together at the extremities of branches as cones. Some plants are homosporous and others heteros-porous. The prothallium is an independent sexual generation resulting from the germination of the spores and bears the sexual organs. In the case of homosporous plants the prothallia are quite independent plants and in heterosporous forms the prothallia develop within the spores and never emerge from them.

Selaginella may be considered to be a form leading from Pteridophyta to seed-plants. The microspores and mega-spores of this plant are homologous respectively with pollen grains and ovules. In seed-plants the pollen grains alone get detached from the sporophyte. In Selaginella, on the other hand, megaspores as well as microspores are shed before germination and are not borne by the sporophyte.

CHAPTER XXV

THE MOSS PLANT

MOSSES are the simplest land plants occurring everywhere massed together in clumps or cushionlike masses. They grow on tree trunks, logs, rocks and in the soil. Many of the mosses dry up and revive again when moisture is available.

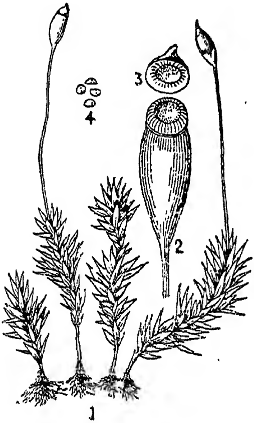


FIG. 458. A Moss plant. 1, the moss plants, male and female; 2, 3, the spore capsule and lid; 4, spores.

A moss plant is an erect, low, green plant having a very slender small stem covered all round with small green leaf-like structures. These structures although called leaves are not really leaves and they do not in any way correspond to the leaves of flowering plants. (See fig. 458.) The so-called leaves are spirally arranged round the stem and they consist of only one layer of cells except in the midrib. The stomata so characteristic of the leaves of flowering plants and ferns are absent.

These plants have no true roots, but send into the soil elongated hairs, called rhizoids. A large number of rhizoids are found at the base of the stems. (See fig. 458.)

Branches arise as adventitious structures from the lower portions of stems and never from the axils of leaves.

The leafy moss plant is the gametophyte bearing antheridia and archegonia. These sexual organs are usually borne by the plants, at the top of the shoots amongst leaves, which are usually crowded very much and somewhat larger than the leaves below. In some species both antheridia and archegonia are found on the same plant, and in others on different plants. The **antheridia** are club-shaped bodies

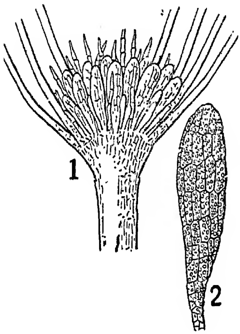


FIG. 459. Antheridia of a moss. 1, antheridia at the end of a branch; 2, an antheridium.

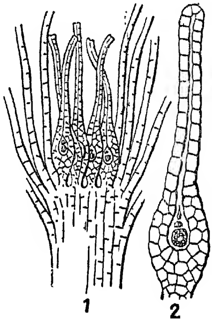


FIG. 460. Archegonia of a moss. 1, archegonia at the end of the branch; 2, a single archegonium in section.

developing in large numbers towards the ends of shoots amidst a number of peculiar hairs. (See fig. 459.) An antheridium consists of a thin wall of large flat cells enclosing a large number of cells which develop into antherozoids. Mucilage is formed within and this swells by absorbing water and bursts open the antheridium at the top. Thousands of sperms or antherozoids escape. Archegonia also are found at the free ends of stems mixed up with hairs. An archegonium consists of a flask-shaped body and a fairly long neck.

After fertilization the egg-cell grows into a small elongated structure whose lower end becomes sunk in the tissue of the tip of the shoot. Then as this embryo grows, the lower flask-shaped body of the archegonium also grows. Very soon the embryo begins to elongate into a long stalk-like body carrying with it the upper portion of the archegonium which gets ruptured at the middle of the venter. Towards the free end of this rapidly growing stalk-like embryo, there arises a capsule-like structure which is hidden beneath the archegonial portion which is more or less like a fool's cap **(calyptra)**. This stalked body or sporogonium is the sporophyte generation of the moss plant. In Pteridophyta the conspicuous well developed large plant is the spore-bearing generation, but in the moss plant it is a small one. Further instead of growing as an independent plant, it is dependent on the sexual plant and derives nourishment for its development from the gametophyte.

When fully formed a sporogonium consists of a stalk and a capsule. On removing the cap at the top of the capsule is seen a lid which comes off easily. The mouth of the capsule bears a row of teeth radiating inwards from the rim. The teeth are hygroscopic and so in dry weather they bend upward and allow the spores to escape and in moist weather they all bend down and close the cavity of the capsule. (See fig. 458.)

The spores are very small and on germination they develop a tangle of very fine small green threads. Buds develop on these threads called **protonema**, and these develop into moss plants or the sexual generation.

CHAPTER XXVI

THE LIVERWORT

Like mosses liverworts also are of no economic importance. They flourish in ditches, beds of rivers, on protected rocky ledges, and in fact, in any place where there is enough moisture. They do not generally attract our attention very much as they flourish in nooks and corners.

We may choose as an example of this group of plants *Marchantia polymorpha*. This plant occurs in all parts of the world, and it is easily procurable in all stages of its development.

The thallus or the plant body of this plant is a dark green ribbon-shaped flat plate which goes on growing forward and branching dichotomously. Very often these liverworts form large continuous patches covering the ground like a carpet. The older portions of the thallus may die, leaving the younger parts to develop as independent plants.

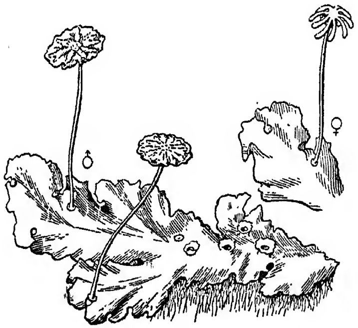


Fig. 461. *Marchantia polymorpha*; male and female plants.

When fully mature the thallus is about two centimeters in breadth and it has a midrib in the middle. Masses of rhizoids arise from the midrib on the lower surface of the

prostrate thallus, and these fix the thallus to the ground. In addition to these rhizoids, two longitudinal rows of scales consisting of a single layer of cells are borne by the thallus, on the lower side, one on each side of the midrib.

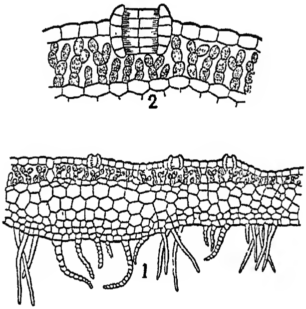


FIG. 462. *Marchantia polymorpha.* Section of the thallus showing the air chambers and the ventral portion, rhizoids and scales. 1, the whole thickness of the thallus with rhizoids and scales; 2, the dorsal portion only showing the air chamber and the air pore.

The dorsal side of the thallus is provided with a large number of air chambers roofed over by the epidermis. These chambers appear as rhombic areas even to the naked eye. In the case of each of these diamond shaped areas, there is a pore leading into the interior of the chamber. The roofing membrane of the chamber in which there lies a pore is the epidermis. The air-pore is in the form of a short canal bounded by tiers of cells. (See fig. 462.) From the bottom of each of these air chambers several rows of cells containing chloroplasts arise. The development of these chlorophyllous cells in short rows leads to an increase of the assimilating surface, and these cells are also placed in direct contact with the atmospheric air by means of the air-pores. These elaborate structural adaptations enable this liverwort to carry on the photosynthetic work as vigorously and as efficiently as the higher land plants. The cells forming the bulk of the ventral part of the thallus are usually colourless, though a few small chloroplasts may be found scattered within these cells here and there.

The rhizoids are tubular prolongations of the epidermal cells and their chief use is to fix the thallus to the ground. Water is absorbed mostly by the plant body itself, as it is spread out and is in direct contact with the moist substratum.

In the region of the midrib and on the upper surface of the thallus some small cup-like structures are occasionally produced. Within these cup-like outgrowths or **cupules** as they are called numerous oval shaped, flat, budlike bodies are formed. These bodies are called **gemmæ**, and each of them is capable of developing into a plant.

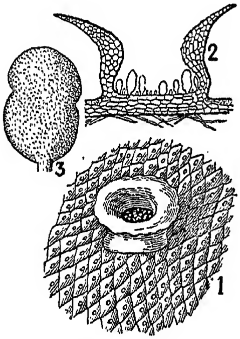


FIG. 463. *Marchantia polymorpha*. A portion of the thallus with cupules. 1, a portion of the thallus showing a cupule; 2, the cupule cut through; 3, gemma.

The thallus of Marchantia corresponds to the prothallus of a fern although its structure is more complicated than that of a fern. Like the prothallus, the thallus of Marchantia bears the sexual organs and so this is the sex bearing plant or the **gametophyte**. There are two kinds of plants, male and female, and these are shown in fig. 461. In the male plant the disc-like bodies borne by the stalks are receptacles containing many antheridia. The receptacles are somewhat circular and their upper surfaces have radiating furrows. There are minute openings which lead into flax-shaped cavities in which the antheridia are lying.

The archegonia also are borne by special stalked star-shaped receptacles. These receptacles are deeply lobed, and the lobes are cylindrical. The archegonia are found in rows in the furrows between the lobes and they are similar in structure to those of the mosses. The egg-cell lies in the lower portion or the venter of the archegonium and the neck

cells disappear leaving the passage clear for the entrance of the sperm cells.

After fertilization the egg-cell grows, divides into a mass of cells, and this mass of cells ultimately develops into a stalked capsule filled with spores. The sporangium and its stalk is the spore bearing generation or the sporophyte, corresponding to the fern plant which bears spores. The sporophyte of the liverwort has an absorbing organ called "the foot" which is attached to the receptacle. A number of sporophytes appear on the receptacles. So a gametophyte produces a number of sporophytes.

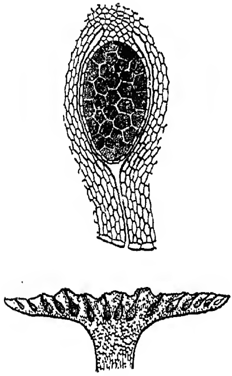


FIG. 464. *Marchantiu polymorpha.* Section of a receptacle showing the antheridia; one antheridium is separately shown on a larger scale of magnification.

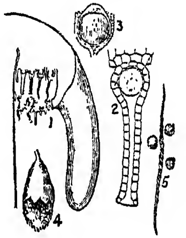


FIG. 465. *Marchantia polymorpha.* The female receptacle showing the row of archegonia 1, a row of archegonia; 2, an archegonium; 3, young sporangium; 4, dehiscing sporangium; 5, elater and spores.

The sporangia burst open irregularly and the spores are exposed. Within the sporangium, in addition to the spores, curiously elongated fibre-like cells having spiral thickenings are formed. These are called **elaters**. By their hygroscopic movements, these elaters loosen the spore masses and help in dispersing the spores. The spores give rise to the gametophyte or the sexual generation.

Another liverwort fairly common in the plains, namely, *Riccia sanguinea*, Kashyap; may be taken as the next type of this group of plants. This liverwort is circular in shape lying flat on the wet surface being attached by the rhizoids. The thallus is ribbon-shaped, short and the branching is dichotomous. As the growth of the thallus takes place radially in all directions the plant is circular. (See fig. 466.)

These plants are green at first, but sometimes when old become reddish in colour. The thallus is very simple and uniform in structure. All the cells are more or less alike and contain chloroplasts. The antheridia and archegonia occur on the same plant. The sporophytes consist of only the spherical sporangia without stalks imbedded in the thallus.

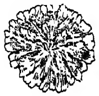


FIG. 466. *Riccia sanguinea*, Kash.

Another inconspicuous liverwort, *Anthoceros lævis* may also be examined. This occurs as small green irregular patches amidst grass soon after the rains. The thallus is simple in structure and rests more or less like Riccia on the substratum.

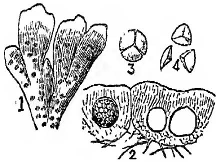


FIG. 467. A portion of the

1, thallus; 2, section with sporocarps; 3 and 4, spores.

generation. The sexual archegonia and antheridia, are found upon the upper surface. After fertilization sporogonia are developed and these bodies differ from the sporogonia of Riccia and Marchantia. The sporogonium of Anthroceros is a slender elongated body, bearing spores in several cavities. On the surface of the sporogonium air spaces, chlorenchyma and stomata with guard cells occur. The sporogonium is the sporophyte generation and it is capable of making its own food though it is dependent on the gametophyte for water and salts.

The life cycle of all liverworts consists of the two generations gametophyte and the sporophyte, one alternating with the other regularly. The gametophyte is invariably the more conspicuous generation, the sporophyte always appearing as an appendage of the gametophyte. But we have already seen that the gametophyte is small and inconspicuous though independent and that the sporophyte is independent and very large in the ferns.

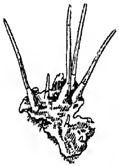
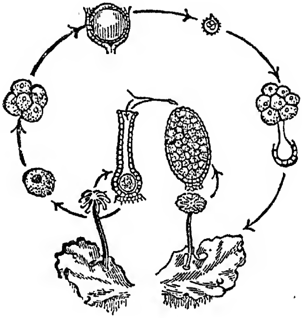


FIG. 468. *Anthoceros lævis.*



G. 469. The life cycle of a liverwort.

CHAPTER XXVII

ALGÆ

THE algæ live mostly in water or in damp situations on the land. The green scum and the tangles of green threads lying on the surface of the water or near it are all algæ. All the green pond scums and green filaments found in fresh water are called Green Algæ. They are most diverse in size, form and habit. Whatever their form and size, all of them possess well differentiated cells containing bright green chloroplasts. The filamentous algæ are made up of rows of green cells. Others consist of green cells variously arranged or of only a single cell.

PLEUROCOCCUS

As an example of algæ of the simplest structure, we may examine the plant which forms green patches on moist bricks, walls, flower pots and barks of trees. In dry weather these patches consist of somewhat dark green powdery substance and when moist they become bright green. If a small speck of this green coating be examined under a microscope, several minute plants of various kinds will probably be seen. Some of them are very small, round, green cells, and they are either single cells or two, four, or more cells aggregated together. This plant is likely to be most abundant and it is called *Pleurococcus vulgaris*.

The single cell is really a separate individual plant. Although it is very minute, the diameter being about 1/2000 inch, it is capable of independent existence. There is a cell-wall enclosing the protoplasm, in which is imbedded a chloroplast. Very often the chloroplast is lobed. Within the protoplasm a nucleus also can be made out, but only by special treatment of the cell.

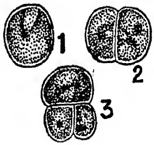


FIG. 470. Pleurococcus. 1, a single cell; 2, two cells; 3, colony of three cells.

Considering the habitat of Pleurococcus it is obvious that it is exposed to dry as well as moist conditions. It has also to endure extremes of temperature. When water is available these plants grow rapidly, and also multiply rapidly. Under dry conditions growth is at a standstill and the plants, as it were, remain in a resting condition. The green patches during dry hot weather retain the same size, but in moist weather there is very rapid extension of these patches. These plants obtain water and also carbon dioxide, and they contain the chloroplast. So they are able to carry on the work of photosynthesis. All the nutritive processes taking place in green higher plants go on also in these small plants. Respiration also goes on. As the amount of water and salts needed for them is so very small in quantity, they manage to get everything they want even in their habitat which is not very favourable.

Each individual, as soon as it attains its adult size, begins to divide and form two cells. If these two daughter cells separate, each becomes a separate individual and assumes a globular form. But very often, instead of separating, they remain together forming a colony of two cells. By further division the colony may come to consist of three, four, or more cells. When the cells form a colony, the sides in contact become somewhat flattened.

Pleurococcus is found all over the world. When the habitat of this plant becomes dry, the patches become powdery and then it is easily caught up by the wind and wafted away, in all directions. This is why it is cosmopolitan in its distribution.

This plant is of special interest as both its structure and life history are alike very simple. All the life processes essential for the well-being and growth of a plant are carried on by these plants. Further all higher plants are undoubtedly descended from unicellular green algæ similar to the Pleurococcus.

Our next example of green algæ is Spirogyra. The slender, long, somewhat slippery green threads forming a part of the green tangles on the surface of water in still ponds and tanks are species of Spirogyra.

When viewed under a microscope it is very attractive on account of the beautiful green spirals found inside the filament. These filamentous plants are called Spirogyra,

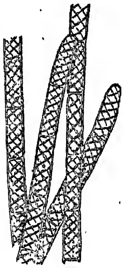


FIG. 471. Spirogyra.

because of these spiral bands which are really chloroplasts. Each filament consists of a row of cells placed end to end. The cells are cylindrical and are longer than broad. The cell wall is fairly thick and the transverse partitions between the cells are straight. The terminal cell in a filament has its free end rounded. In the centre of the cell lies the nucleus which is swung as it were by fine threads of cytoplasm connecting the cytoplasm around the nucleus with the peripheral layer of cytoplasm. The nucleus is generally not easy to see, as the chlorophyll bands usually lie above the nucleus. In a species of spirogyra in which the spirals are not close, the nucleus is readily visible.

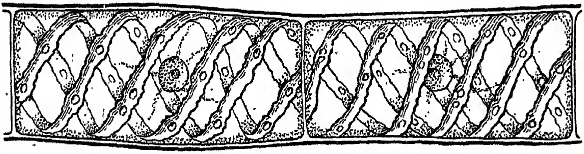


FIG. 472. Spirogyra; two cells very much magnified.

The chlorophyll bands occupy the peripheral portion of the cell and the spiral bands in the cells vary in number

according to the species. In some species there is only one spiral, in others two ; three or more spirals also occur. These bands are fairly broad with irregularly notched edges. At intervals, in these bands, we find small round refractive bodies called pyrenoids. Around these pyrenoids the starch grains accumulate forming a kind of jacket.

All the cells in a thread are alike and every one of them is capable of division and growth. At first the nucleus divides into two and afterwards the cell divides. It is by cell division and growth of these cells in length that the filaments become longer. Sometimes the spirogyra filaments get broken, and these broken fragments are capable of elongation. By repeated breaking and growth the filaments

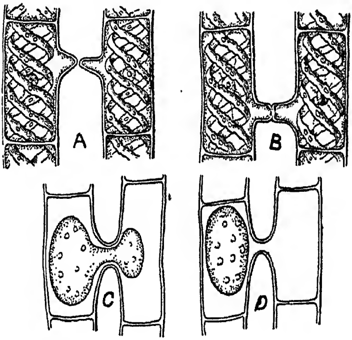


FIG. 473. Spirogyra filaments in different stages of conjugation. A, filaments in which processes are just forming ; B, the processes fused ; C, the contents passing into the other cell and fusing ; D, zygote.

may go on increasing in number. This vegetative mode of multiplication is quite common in the case of spirogyra. In addition to the vegetative propagation, it reproduces itself by a kind of sexual reproductive process called **conjugation**. If old discoloured threads are examined, there will be found some threads which are in pairs, the two being connected together by tubes passing from a cell of one filament to another cell opposite to it in the other. In the cells of one of the filaments oval bodies will be seen, while

the other filament will have none in its cells. These bodies are zygotes and each zygote germinates and develops into a filament of spirogyra under favourable conditions. From the fact that in the connected filaments only one bears the zygotes, we have to infer that the zygotes are formed by the fusion of protoplasm of two cells.

The process of conjugation takes place in spirogyra in the manner described below. Two filaments come together and lie parallel. The cells put forth small processes in both the filaments simultaneously. These processes from two opposite cells meet, and a free passage is formed from one cell into the other. The protoplasm in the cell, at the same time, shrinks away from the wall. Then it begins to move towards the connecting tube, and a portion of it with one end of the chlorophyll band gets into the tube. Similar changes take place in the protoplasm of the other cell, lying opposite to the cell whose protoplasm has found its way to the tube. Finally the whole of the protoplasm passes through the connecting tube and goes over to the other cell. Both the masses of protoplasm fuse and the zygote is formed.

On account of the fusion of two masses of protoplasm this is to be considered as a kind of sexual act. The filament in which the zygote is formed, being passive it may be considered to be the female, and the other filament from which the protoplasm moves into another filament to be the male.

The spirogyra also is as simple as the pleurococcus in its mode of life. Though the cells are united together in rows, every one of the cells can carry on its functions quite independently, the only difference being a slight advance in the matter of propagation. In spirogyra in addition to the vegetative propagation, there is also the sexual mode of reproduction, the conjugation.

Another interesting alga, *Botrydium granulatum*, growing on moist earth may next be considered. This plant occurs in masses in the clay of drying up ponds, ditches or flooded plains.

The plant is unicellular and consists of a small balloon-shaped green ærial portion, about the size of a pin's head and an underground portion consisting of numerous white branches, formed by repeated forking. Although unicellular

like Pleurococcus, this is comparatively very much larger than that plant and shows a certain amount of differentiation. The ærial part is green and somewhat rounded and the underground part is white and branched very much. This may be considered as a physiological differentiation into root and stem, seen in higher plants. The cell has protoplasm in it, but instead of one nucleus, it possesses several nuclei embedded in the thin layer of protoplasm lying near the cell wall. Numerous chloroplasts also occur in the protoplasm. The ærial part being green can carry on the work of photosynthesis, and the underground white branched portion absorbs water and mineral salts.

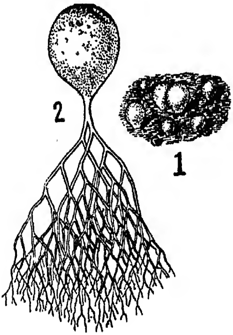


FIG. 474. *Botrydium granulatum.* 1, a colony; 2, a single individual plant.

The propagation of this alga is by means of small motile bodies called zoospores. When submerged under water, the inflated ærial portion produces inside a large number of uniciliate zoospores. These zoospores may either germinate immediately or become resting spores. If the ærial portion instead of being under water, be exposed to drought, the contents retreat into the branches lying in the substratum and become changed into a large number of non-motile spores. Sometimes a small bud is formed from the ærial portion and this grows and produces branches which find their way into the soil and then gets separated from the parent and becomes an independent plant.

Besides the green algæ there are algæ flourishing in water as bluish green scums, especially where organic matter is abundant. They impart to the water a very offensive smell. These are called bluegreen algæ, and the plant body consists of single cells or colonies of cells or of threads. The main difference between these and the green algæ lies in the chloroplasts. In the blue green algæ no chloroplast is present, the blue-green colour being due to a liquid diffused through the protoplasm, whilst it is present in the green algæ.

In sea water also some algæ occur. These are called Brown or Red Algæ according to their colour. They are most varied and assume large sizes and spread wide.

The green algæ is more advanced than the blue-green algæ. Although the lower forms are unicellular, the higher forms are multicellular, some forming flat plates and others filaments. In some cases there is no differentiation of cells, but in the higher forms, some cells alone are capable of producing spores or sexual cells. The sex cells are similar in some and in others they become dissimilar, thus leading to the next higher group Bryophyta.

CHAPTER XXVIII

FUNGI

THE fungi form a very large group of Thallophyta. There are many kinds of fungi, such as the moulds, mildews, rusts, smuts, toadstools and mushrooms.

The most striking feature of the fungi is its mode of nutrition. They are lacking in chloroplasts which are abundant and are so characteristic of the algæ and higher plants and, therefore, fungi are unable to make their own food. As a rule these plants are dependent on other plants or animals for their food. Some of them obtain their food from living organisms and they are called **parasites**, while others depend upon the dead remains of plants or animals or upon products produced by them for their food and they are termed **saprophytes.**

From an economic point of view the fungi are most important, because most of the plant diseases are caused by them. Now a days a considerable amount of attention is bestowed on the study of these plants as to their life history. For controlling the disease, a knowledge of the plant bodies, mode of reproduction and how they use their hosts is essential. Without this knowledge it is not at all possible to check the disease from spreading, and much less to eradicate the disease.

RHIZOPUS NIGRICANS

The bread mould *Rhizopus nigricans* may be taken as our first example of fungi. This is a saprophyte occurring commonly on bread, although it occurs on fruits, such as plantain. When a piece of wet bread is kept in moist air under a bell-jar for a day, a white fluffy tangle having a cob-webby appearance forms on its surface. This fluffy mass is the plant body of the fungus. This is made up of a large number of white threads running in all directions, some horizontally, a few vertically downwards. On examining

these threads, which are called hyphæ, they will be found to be without cross-walls. As a matter of fact the whole plant body or the fluffy mass when young is a single cell. It branches freely and goes on all sides.

In this plant we just see the beginnings of division of functions. The horizontal threads or hyphæ grow upon or near the surface of the bread and thus lead to the further spread or extension of these threads all over the bread. Those that grow in groups from the horizontal branches downward into the substance of the bread absorb the food materials, after altering the colloidal substances into soluble forms. The somewhat stouter hyphæ arising later, from the horizontal branches, from about the same places at which the groups of threads going vertically downwards start, grow upwards into the air and develop sporangia at their free ends.

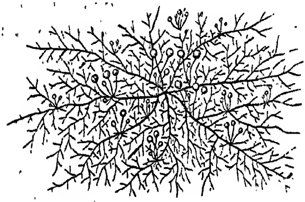


FIG. 475. Mycelium of *Rhizopus nigricans.*

When a mould is young it is fluffy and white, but as it gets older it becomes brownish and powdery in appearance, and a large number of distinctive spots also appear. These black dots are sporangia. It is only after the mould has been growing for sometime and has reached a considerable size that the erect branches begin to appear. The tip of the erect hypha swells at first and then it is separated from the rest of the thread by the formation of a cross-wall. This swollen portion grows, forms a globular body which later becomes a spore sac. When the sporangium is in the course of formation, we see sometimes the protoplasm moving very trapidly towards the tip from the lower portions of the erec

hypha. The protoplasm within the swollen portion changes into a number of small spores. When the sporangium is ripe its wall bursts and the spores are liberated. The spores being very minute and light float in the air and are easily carried about by currents of air. So these spores are found in the air practically everywhere and this is why this mould nearly always appears on moist bread.

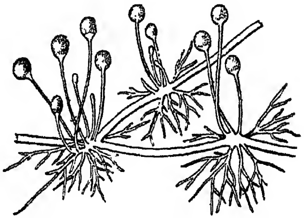


FIG. 476. Sporangia and spores of Rhizopus.

The spores can remain dormant for a long time in a dry place without germinating. As soon as a spore falls in a place favourable for growth it germinates and produces a mycelial thread, which by further growth and branching assumes the condition of the mature plant.

In *Rhizopus nigricans* in addition to the formation of spores in the manner above described, there also occurs a sexual method of reproduction similar in some respects to that of spirogyra. Hyphæ developed from two different spores sometimes approach, the free ends meet, the tips become swollen and from each hypha the end cell is cut off by the formation of a wall. Then the contents of these two cells fuse and a **zygospore** is formed. On germination this zygospore gives rise to an erect hypha which produces at its free end a sporangium of the ordinary type. The formation of the zygospore takes place only when the end cells, or **gametes** as they are called, that unite belong to two separate plants which belong to two different strains. These strains are spoken of as plus and minus strains. When both the strains are present in the culture, conjugation occurs abundantly. If either of these occur alone in the culture, no conjugation takes place.

Puccinia Purpurea

As our next example we may choose this fungus which causes the rust disease in the cholam plant (*Andropogon sorghum*). The presence of this fungus is indicated by the reddish streaks or spots found on the leaves and stems. The mycelium is internal and traverses the tissues of the leaf and the stem.

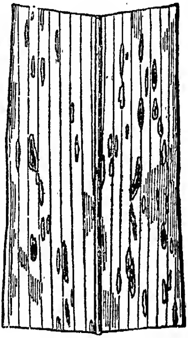


Fig. 477. Rust on cholam leaf.

If we examine the red spots they will be found to be really small pustules roofed over by the epidermis. When young the epidermis is intact, but in old pustules this will be burst open. These pustules are in fact clusters of spores borne by the ends of the erect hyphæ that have come out. The spores found in these pustules are mostly unicellular,

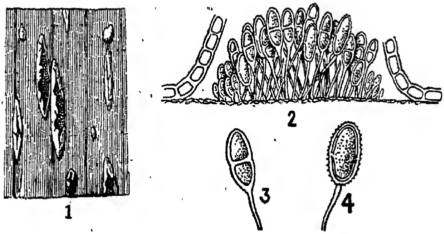


Fig. 478. Uredospores and Teleutospores of *Puccinia purpurea*. 1, sori on cholam leaf; 2, one sorus cut through; 3, teleutospore; 4, uredospores.

reddish in colour and somewhat rough on the surface. These spores are called **uredospores** or summer spores. By means of these spores the disease spreads rapidly and widely through the growing cholam plants. The spores fall on the leaves or stems, germinate there and the hyphæ get into the tissues through the stomata.

During the earlier part of the life of the host plant, the rust spots contain only uredospores. But later on another kind of spores called, **teleutospores**, is also found amidst uredospores. These teleutospores are two celled with thick smooth walls. When the cholam crop is very much advanced uredospores become rare and teleutospores appear in abundance. The spots at this stage consists wholly of teleutospores and they look somewhat darker than when they consist of uredospores.

Puccinia is a very interesting parasitic fungus with a somewhat complicated life history in the case of some species. In the cholam plant the life cycle of this rust seems to be extremely simple, the propagation of this fungus being mainly by means of uredospores. How the cholam plant gets infected in the seedling stage and what happens to the teleutospores and what part these spores play in the life cycle of the rust fungus are problems awaiting solution.

The life history of the species *Puccinia graminis* causing the rust of wheat is now well known. As soon as the fungus is well established in the tissues of the wheat plant, pustules appear on the leaf-stalks and leaves. These pustules are clusters of spores called **sori**. The spores are uredospores or summer spores. The uredospores, if carried to other wheat plants, may germinate and infect the plant. So these spores can carry the infection from one wheat plant to another, and if the conditions are favourable the whole field may get infected in this manner. Later towards the end of the growing season the rust produces teleutospores. Some sori may contain both uredo and teleutospores, although most of the sori formed contain only teleutospores.

The teleutospores by reason of their thick walls, can endure unfavourable conditions. Therefore, we may consider teleutospores as representing a stage in the life history of *Puccinia graminis* intended to enable it to live through the

unfavorable season, winter. These spores probably remain in the ground, or may get scattered. As soon as some warmth and moisture is available during spring these spores germinate and give rise to hyphæ with small septate cells towards the end. From these cells small stalks arise bearing spores. These spores are called **basidiospores.** It is interesting that the hyphæ resulting from the germination of teleutospores is saprophytic in its mode of nutrition.

The basidiospores do not affect the wheat plant. They prefer a different host. These spores on reaching the barberry leaves germinate and infect this plant. As soon as the hyphæ formed from the spores get into the interior of the leaf through their stomata, an extensive mycelium is formed within the tissues of the leaf. After a time the hyphæ come out here and there on the lower surface of the leaf in compact masses and form small cup-like structures. These hyphæ change into a large number of spores. The cups are called **aecidia** and the spores **aecidiospores.** It is these aecidiospores that infect the wheat plant.

In Europe early in the eighteenth and nineteenth centuries people were aware that the presence of barberry plants was responsible for the "rust" or "blight" of the wheat crop. During the latter half of the nineteenth century De Bary worked out the life history of *Puccinia graminis* and proved that the rust on the barberry plant and that on the wheat are only different stages of the same fungus, and that two host plants are necessary for this parasitic fungus to complete its life history. Thus we see that the wheat rust fungus forms four distinct kinds of spores, the uredospores and the teleutospores developing on the wheat plant, the basidiospores forming on threads that are saprophytic and the aecidiospores on the leaf of the plant Berberis, quite a different host plant.

Smuts.

The smuts are parasitic fungi affecting mainly the cereals and the grasses. They chiefly attack the floral organs, although they may affect other parts also. They cause extensive damages to the grain in the cereal plants.

The mycelium of this fungus infects the cereal plant in the seedling stage and gets started in the tissues of the plant. As the cereal plant grows, the mycelium also grows and extends into all the parts of the plant. At the time of the flowering of the host plant the mycelia penetrate into the ovaries and consequently they become swollen, distorted and appear as tumour-like growths. Instead of the grain, we find a

FIG. 479. *Tolyposporium filiferum* (the long smut of cholam).

mass of spores in the tumour-like swelling occupying the position of the grain. The hyphal threads getting into the ovaries become changed into spores which are usually black. These spores are called **brand spores** or **chlamydospores.** Each spore has a fairly thick wall.

These spores get dispersed and remain in the soil or they may stick on to the leaves, or grains of the cereals. On germination, each of these spores produces a short septate hypha on which **basidiospores** arise. Infection may take place by the chlamydospores lodging on the grain or the glumes. The basidiospores also are capable of starting the disease in the tender parts of the cereal plant. There are two smuts affecting the cholam plant (*Andropogon sorghum*). One is the long smut caused by the fungus *Tolyposporium filiferum*: and the other short smut caused by *cintractia sorghi vulgaris*.

Another fungus causing smut in *Setaria italica* is *Ustilago crameri*. All these smuts seem to infect the plants in the seedling stage only. The spores seem to adhere to the surface of the grain, germinate along with the seed and enter the seedling.

The Mushroom.

The mushrooms are the largest and the best known of the fungi.. They flourish best and are abundant in damp shady woods in fields and gardens. They are mostly saprophytes obtaining their food from decaying wood, leaves and manure. Some are parasitic on roots or other parts of living plants.

What we call a mushroom is the ærial fruiting or spore producing part of the plant. In a mushroom we find a

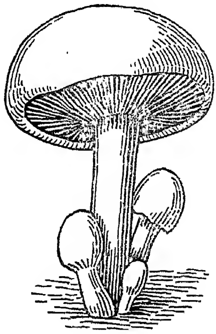


Fig. 480. A mushroom (*Agaricus campestris*).

stalk called the **stipe** and an umbrella-like cap on it which is termed the **pileus.** The stalk of the mushroom consists of a large number of well-compacted hyphæ running longitudinally. In the pileus there are a number of lamellæ or gills on the lower side. These gills extend from the central portion, where the cap joins the stalk to the edge of the cap, like the spokes of a wheel. Each of these gills consists of a mass of hyphæ running in all directions. Some of these hyphæ grow out at the surface of the gills and their free ends become swollen. The central core of the gill which is made up of hyphæ running on all directions is called the **trama.** The external portion of the gill which consists of the erect hyphæ with swollen tips is called the hymenium. The swollen tips of the hyphæ are termed **basidia.** Each basidium has two slender stalks bearing spores **(basidiospores).**

If a ripe pileus with its gills is placed on paper, after some hours the basidiospores would be found to have fallen on the paper in radiating lines. If the spores are black, white paper and, if white, black paper should be used to see the lines of spores well by contrast. Mushrooms are propagated only by their basidiospores and no sexual mode of reproduction is known amongst them.

The vegetative body corresponding to the mycelium of the fungi already described is underground. The stipe of the mushroom is continuous with a number of whitish branching threads (rhizomorphs) running through the substratum in all directions (See fig. 481). These white strands are really the bundles of hyphæ corresponding to the mycelium of Rhizopus. The mushroom or the ærial part corresponds to the erect hypha bearing a sporangium or a spore sac.

The fruiting body appears at first as a small white knot on the underground mycelial strands. This knot consists of hyphæ interwoven and packed rather closely so as to form a compact mass. As the threads of the knot grow and develop, the knot enlarges and looks like a round button. By further growth the button changes into the fruiting body of the mushroom.

The mushroom *Agaricus campestris* is largely used as food. So it is largely cultivated. Beds are prepared consisting

of soil rich in organic matter or manure. Small portions of the soil or other substratum in which the mycelial threads or strands are plentiful are distributed through the soil of the beds. The small portions or bits containing the hyphæ are termed "mushroom spawn." It must also be remembered that there are several species of mushrooms which prove fatal if used as food as they are poisonous.

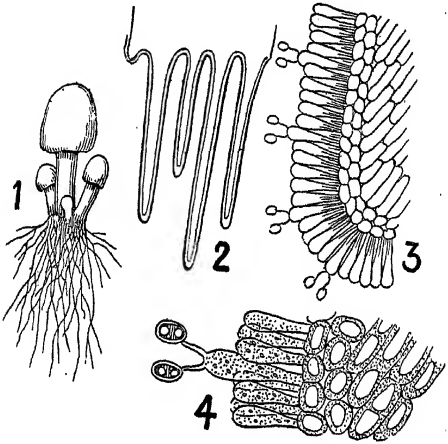


FIG. 481. Parts of the mushroom and their structure. 1, spore bearing portion in a very young stage; 2, gills slightly magnified; 3 and 4, hymenial surface showing basidia and spores.*

The mushrooms belong to a big group of fungi called Autobasidiomycetes and to the section Agaricales. The Agarics or the gill fungus has its hymenium on the gills. In some the hymenium covers tooth-like processes. There are also some fungi in which the hymenium lines the tubes which terminate on the lower surface with pore-like openings.

BACTERIA.

Bacteria are the smallest of plants and, therefore, they can be seen only under a very high power of magnification of the microscope. Some of the round bacteria are about 0·0005 of a millimeter or even less. Some hold that there

are also bacteria so minute that they cannot be seen even under the highest powers of the microscope. They abound everywhere, existing in the air, in the soil, in water and in fact on everything.

A bacterium is a small single cell with a delicate cell wall enclosing protoplasm not differentiated into a nucleus and protoplasm. As the bacteria do not contain chloroplasts, their mode of nutrition must be similar to that of the fungi. They change the nature of the organic substances in which they grow by means of enzymes. One characteristic of bacteria is their power of changing the chemical nature of substances with which they come in contact. The processes we call fermentation and putrifaction are brought about by bacteria. The general decay of the debris of plants and animals and their transformation into simpler substances is mainly brought about by bacteria. The accumulation of debris of organic matter is prevented by the action of bacteria, thus rendering the surface of the earth habitable both to animals and plants.

Reproduction amongst bacteria is by cell division. Multiplication is generally so rapid that in one day several billions are formed.

Amongst bacteria there are both useful and harmful ones. As examples of useful ones we may mention the nutrifying bacteria which at first change ammonia into nitrites and then nitrites into nitrates. There are bacteria in the soil which are able to form nitrogen compounds by utilizing the nitrogen found in the atmospheric air. The nitrogen compounds are used in building up their own bodies and when their bodies decay there is accumulation of nitrogenous compounds in the soil. We should also mention here the bacteria found in the root nodules of leguminous plants, as they also utilize the free nitrogen for making nitrogenous compound for their use. As examples of bacteria causing disease we may mention those that produce the diseases of cholera, tuberculosis, tetanus and plague. Bacteria cause disease in plants also.

If we consider the forms of the plant body of bacteria there are three forms—globular ones called coccus forms, rod-like called bacillus forms and curved rods termed spirullum forms.

CHAPTER XXIX

ORGANIC EVOLUTION

We know that the vegetation on the surface of the earth consists of many species, some simple and others highly organized. It is but natural for any one to ask how all these species of plants came into existence. Some would readily answer that plants as well as animals were created by the Creator. As a matter of fact, before the middle of the nineteenth century, many theologians and men of intellect believed that plants and animals were created in the beginning, as narrated in the Bible. If this Doctrine of Special Creation is accepted, we are bound to assume that creation has taken place once and for all in the beginning, and that every species of plant or animal thus created has remained constant in all fundamental features until the present time. In other words, it means that flowering plants, ferns and other groups of plants, however simple or complex, have been in existence practically ever since the world began without much change. This conception of the fixity of species could not, however, be supported by facts.

In the study of various species and groups of plants, we assumed that the complex forms of plants have come from simpler ones by gradual modifications. Evolution means gradual change, and the idea that plants and animals living at the present time are the lineal descendants of ancestors which are simpler, and that these were descended from yet simpler ones that lived in still older times is **Organic Evolution.** Organic evolution teaches us that plants and animals are subject to a continuous process of change which is operating from the beginning without stopping and which is still in progress. In other words, we have to understand that living beings were not in the beginning as we now find them, but that there have been constant changes in them. A general review of the Flora and Fauna of the present and past ages shows that in the early history of the world there were only simple plants and animals, and that the complex forms came

into existence only later. The highly organized plants must have been derived from simple plants such as Pleurococcus through changes involving many thousands of years. The developmental history of an individual **(ontogeny)** from a spore or that of a group of related forms **(phylogeny)** tell the same story. One chief aim of Botany and also of Zoology is to record, as far as it is possible, and in order, the evolutionary steps that have culminated in the present condition of the plant and animal world.

From a study of nature we learn that at the present time living organisms come into existence by the method of reproduction of organisms already existing. This must have been the method always. After the first appearance of life, living things have been derived from pre-existing organisms. Of course they are subjected to a process of constant though gradual changes. In the vast majority of plants and animals, no doubt, the steps of evolution have been towards greater complexity of parts, increased efficiency in their functions and, in general, towards higher organization. In other words, evolution is **progressive.** There are also instances in which the steps have been **regressive** instead of being progressive. But such ones are not many. For instance, the parasitic plants Cassytha and Cuscuta have become degenerate, and hence the evolution in the case of these plants is obviously regressive.

The theory of organic evolution existed in men's thoughts since Aristotle's time. But until the middle of the nineteenth century it was a mere speculation not supported by any body of facts. From being a mere speculation it became a scientific fact based upon evidence obtained by extensive observation with the publication of Charles Darwin's great book "Origin of Species" in the year 1859. No other book influenced men's thought so much as this book. He holds that species of plants and animals came into existence by the process of evolution and that evolution rests upon **Natural Selection.** The arguments adduced in favour of his views are most convincing and further they are so well based on facts that his theories are now widely accepted. The theory of evolution has become a current coin amongst all biologists and it is a fundamental conception not only in

Botany and Zoology, but also in Chemistry, History and Philosophy. Evolution is axiomatic now-a-days with all the scientists.

As regards the methods of evolution several hypotheses were advanced from time to time. The explanation offered by Lamarck was current for a short time, but very soon it was rejected as being unsatisfactory. According to Lamarck living beings are changed by their environment and also by use and disuse of organs, and then these changes induced in living beings are inherited by their offspring and accentuated from generation to generation. It is true that changes are produced in plants and animals by changes in their environment, or as the result of use and disuse of organs. But we have no evidence that acquired characters are transmitted to the offspring. Experimental proof is also against this view.

No satisfactory explanation was offered until Darwin gave to the world his theory of Natural Selection. Even the conception that evolution is the method of creation failed to win the general acceptance of the educated men, because it was never supported by sufficiently convincing evidence. It was left to Charles Darwin to accumulate overwhelming evidence in support of organic evolution through natural selection. He pointed out that a perpetual struggle is going on amongst plants and animals and that as the result of this struggle only those best adapted to the surroundings survive. Inasmuch as only a few individuals that are fit to survive live and propagate and a large number not fitted to live perish, he considered this to be a kind of selection and called it **Natural Selection.** This theory of Natural Selection, or Darwinism as it is sometimes called, is based upon the fundamental conceptions, increase in progeny, struggle for existence, variation, survival of the fittest and heredity.

Increase in progeny.—Plants produce a fairly large number of seeds. If all the seeds produced by a plant in successive generations were to germinate and grow successfully, there will be no room for other plants. To make this clear we may choose as an example the weed *Argemone mexicana* and consider its behaviour. A single plant of this species produces

from 20,000 to 30,000 seeds in a season. Taking the average number as 25,000, the progeny of one plant would number 15,625,000,000,000 in the third generation if all the seeds are allowed to grow. Supposing each of these plants occupy a square foot, then the plants of the third generation will cover nearly 500,000 square miles. In spite of this prolificity in seed production, we do not find any abnormal increase in these plants in any season, even if the observation is continued through several seasons. About the same number of plants appear year after year. This approximate uniformity in the number of plants of a species, year after year, is due to severe competition amongst them at every stage. All the seeds of a plant do not obtain the condition necessary for successful germination. In the seedling stage again there would be a struggle amongst them for water, salts and light. Only those seedlings that are capable of vigorous growth would be

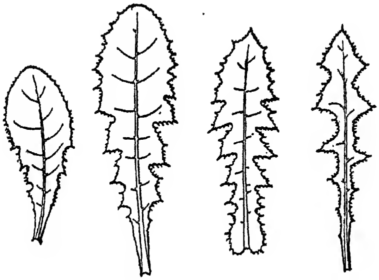


FIG 482. Leaves of *Lactuca Heyneana*, DC., growing on the same plant.

able to survive in the competition. Such seedlings would be able to get more water and light than the others with slow growth. In the end the weaker ones with slow growth must perish. This quality of vigorous growth in the seedling stage is a variation that enables certain plants to survive. But for this variation there would be no selection and survival of the fittest ones. Thus we see that variation is the most fundamental fact in the theory of natural selection.

Variation.—If we look at a number of plants of a species, all of them are alike in many points, and that is why we include them under the same species. But, if we fix our attention on individual plants and examine them closely, we clearly see that no two individuals are exactly alike, and that each has its own individuality. To find out the differences one must be well acquainted with the distinguishing marks of the group of the plants.

Plants vary in all their parts, in every possible direction and to every extent from very small to considerable range. Leaves show considerable variations. For example, if we look at the leaves of the weed *Lactuca Heyneana*, we find them varying very much. (See fig. 482.) Plants under cultivation have a greater tendency to vary than the wild plants. Variations may be either morphological or physiological.

There are two kinds of variations occurring in plants. They are **fluctuating** or **continuous variations** and **discontinuous** or **saltative variations.** The former is of very general occurrence in plants. In this kind the range of variation is very considerable, and further every gradation in size occurs between the smallest and the largest. The fluctuating variations occurring in plants and animals are largely dependent upon the environment. In other words the variations manifested by plants are chiefly due to differences in the environment, such as differences in sunlight, food and water-supply, and influences exerted by one living organism on another. These variations are not inherited and are constantly changing with the conditions that cause them.

Continuous variations fluctuate around a mean or average. They are quantitative. The mean or the average remains practically constant. The individuals having variations above or below this average become less and less in number as the variability departs more and more from the average until a limit is reached in each direction. The number of individuals having a variation which diverges from the mean to a small extent is generally large and individuals with larger divergences are less in number. If we, for example, examine the seeds of a bean plant in a measure of the seeds, no two seeds would be precisely of the same dimensions. In this connexion an actual experiment conducted by Hugo De Vries may be

quoted. He chose at random 450 beans from a quantity purchased in the market and measured them all. The

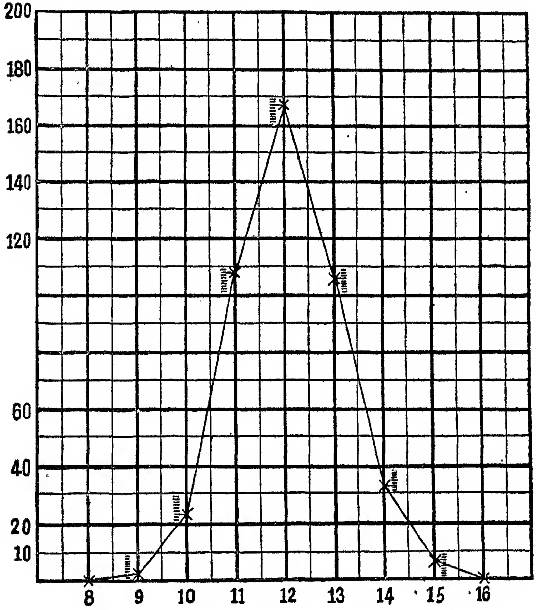


FIG. 483. Curve showing variation in bean seeds. The horizontal numbers are millimeters and the vertical ones are the number of seeds.

variation in length was from 8 to 16 millimeters and the number of seeds of definite measurements were as given below :—

Number of beans-1,-2,-23,-108,-167,-106,-33,- 7,-1
Millimeter 8,-9,-10,- 11,- 12,- 13,-14,-15,-16

He then sorted them in nine compartments according to their lengths. The tops of the columns when joined form a curve resembling somewhat a curve called Quetelet's curve. From the data given above a curve may be plotted. (See fig. 483.) From the curve we see that

the greatest frequency coincides more or less with the mean dimensions and that the more the divergence from the average the less frequent is its occurrence.

As the continuous variations fluctuate around an average from generation to generation in plants, it is not possible to cause any improvement in any variation even by very careful selection. It is not, therefore, possible to obtain any improvement of a permanent character in these continuous variations.

Charles Darwin no doubt recognized these two kinds of variations. But the differences between these two classes of variations and other facts about them were not known then. He attached greater importance to continuous variations, and held that all sorts of differences between individuals as affording the material for the natural selection to work. Hugo De Vries was the first to point out clearly the facts about variation after experimenting. He studied in detail the nature of the discontinuous variations by means of experimental method and gave to the world in the first year of the twentieth century his mutation theory. He called the discontinuous variation **mutation**. Mutations appear suddenly and they are very striking in character and they breed true. He holds the view that species are formed by the selection of mutations and not by the selection of continuous variations. This is the essence of the mutation theory.

Survival of the fittest.—It is obvious that the individuals that survive without perishing in the struggle for existence, must be those best suited for the environment. And the survival is due to their having some variation enabling them to adjust themselves to the environment. Those not possessing this variation cannot adjust themselves and consequently they must ultimately perish.

Inheritance.—We know that the offspring of a species resemble their parents in several respects, though not in every respect. Although there may be variations, plants transmit to their progeny something of their own character. This is inheritance. Both resemblances and differences are transmitted. If individuals possess some variation which enables them to adapt to their surroundings better than others without such a variation, such individuals survive and

propagate, and in the offspring this variation will be pronounced. If this goes on for some generations the variation becomes intensified by natural selection and eventually becomes a character of a new species. We shall conclude this brief account of natural selection by quoting Darwin's own summary of the process :—

"If under changing conditions of life organic beings present individual differences in almost every part of their structure, and this cannot be disputed; if there be, owing to their geometrical rate of increase, a severe struggle for life at some age, season, or year, and this certainly cannot be disputed; then, considering the infinite complexity of the relations of all organic beings to each other and to their conditions of life, causing an indefinite diversity, in structure, constitution, and habits, to be advantageous to them, it would be a most extraordinary fact if no variations had ever occurred useful to each being's own welfare, in the same manner as so many variations have occurred useful to man. But if variations useful to any organic being ever do occur, assuredly individuals thus characterized will have the best chance of being preserved in the struggle for life; and from the strong principle of inheritance, these will tend to produce offspring similarly characterized. This principle of preservation, or the survival of the fittest, I have called Natural Selection. It leads to the improvement of each creature in relation to its organic and inorganic conditions of life, and, consequently, in most cases, to what must be regarded as an advance in organization. Nevertheless, low and simple forms will long endure, if well fitted for their simple conditions of life."

Darwin, Wallace and others held the view that specific distinctions come into existence by natural selection acting upon individual differences. According to this view all kinds of variations though slight are inheritable and they can become intensified through generations of selection and finally become distinct characters of new species. Another theory, the theory of mutation, is offered as an explanation of the origin of species. According to this theory mutations are inheritable and they are not built up through generations of selection, but they arise suddenly, in full force, and breed true. New species arise at one bound, according to this

parent as inheritance a small bit of protoplasm and this bit of protoplasm possesses a tendency to develope only in a definite manner. That is to say, the protoplasm of the daughter cell develops all the characteristics of a Pleurococcus. It works in this manner because its ancestors must have possessed these characteristics for a very long period of time. Thus we see that inheritance is inseparably linked with reproduction. Even in higher plants, so far as vegetative reproduction is concerned, the new plant is obviously a portion of the parent plant, isolated and growing independently by itself. The separation does not affect the protoplasm in any way and so the inheritance also would not be affected.

But the case of the higher plants with sexual reproduction is far more complex and not simple. Complicated changes occur between the offspring and the parents. The formation of pollen grains (male gametes) and the ovules (female gametes) involves reduction division. Again there is the fusion of the contents of the pollen grain and that of the ovule. This fusion of the gametes from two different sources must necessarily lead to considerable alterations of the protoplasm. If the pollen grains and the ovules happen to be those of different plants, then in the fertilized egg are united protoplasms from two distinct lines of ancestry, with two entirely different histories extending far back into the past.

Thus it is obvious that hereditary transmissions must of necessity be most complicated. Different kinds of variations may become involved and they may become associated with different kinds of heredity. So the study of facts of heredity is not an easy matter.

For a long time men tried to study the principles of heredity by the statistical method. Investigators chose characters and noted them or actually measured them in a large number of parents and also in their progeny. Then they used to compare these results and find out the extent of resemblance between parents and children. This method deals with the average of the character observed or measured of a mass of individuals belonging to a species. If the object of study is to see whether a given character is constant, or shifting, or behaving in some other way, this method is a satisfactory one.

If on the other hand, the object is to learn facts of heredity in all its bearings, then this mode of study is not likely to yield any useful result. For the averages arrived at by observing a large number of individuals mean nothing, inasmuch as the mass considered represents a complex mixture of individuals. To arrive at reliable results, it is absolutely necessary to deal with homogeneous material or individuals derived from a common stock and whose pedigrees are known.

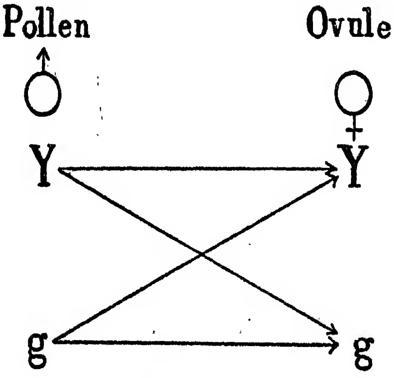
The method of study which has led to remarkable results was first used by Gregor Mendel. He conducted his experiments in his garden and published his results in 1866. But it never saw the light of day until the year 1900, when it was discovered simultaneously by three investigators. Hugo de Vries in Holland, Correns in Germany and Tschermack in Austria. At the present day the workers on these lines are many and are all over the world.

Before Mendel several workers had made many laborious experiments by crossing different races of plants. They thought that hybrids were intermediate between the parents, though they resemble the parents in some features and that crossing of distinct races was a potent cause of variability. But they could not arrange their observations in any order so as to bring them under definite laws. This is because they always regarded the individual as the unit, and we know an individual may have any number of characters. On the other hand, Mendel took as his unit, not the individual, but one character found in an individual, and he always concentrated his attention upon one character at a time. He viewed an individual as being to a large extent an aggregation of separate characteristics.

Mendel, being an investigator of a high order, set about his experimental work in a thorough going and a systematic manner. He chose as his material for study, the edible garden pea plants, as these plants are easy to cultivate. Another advantage is that these plants are usually self-fertilized and therefore plants chosen for parents would be pure. Besides this they could be raised two or three times in a year and they had in them sharply contrasting characters. In the study of

determiner for yellow and the ovule one for green, or *vice versa*, the zygote will contain determiners for both the characters and this kind of zygote is termed a **heterozygote.**

Although the plants of the first generation contain the factors, or genes as they are sometimes called, for both the characters, separation of these characters from each other takes place in the course of the formation of the pollen grains and the ovules. This dissociation of factors from each other is spoken of as the **segregation of the gametes.** When this segregation takes place, the number of pollen grains bearing one factor, say, green would be equal in number to those with yellow. The same is the case with the ovules also. In other words, the number of reproductive cells bearing the determiner for green would on the average be equal to those



$$= YY + Yg + gY + gg$$

$$\text{i.e } YY + 2Yg + gg.$$

carrying yellow. When the plants of F_1 generation are selfed, the reproductive cells of both the pollen grains and the ovules fuse in pairs and they could combine in only four ways. Out of the four gametes present in the plants there is just one chance for the two sexual cells with yellow to fuse and the resulting seed will be a pure yellow; similarly, there is

one chance for the cells with green which will also give rise to a pure green seed; and there are two chances out of four in which yellow will fuse with green. And so there will result one seed pure to yellow, one pure to green and two with both yellow and green. This is exactly Mendel's ratio 1 : 2 : 1. These facts are graphically represented in the diagram on the previous page.

Mendel's theory of segregation and purity of gametes is not a mere speculation. His view that the sexual cells or gametes have in them something upon which the development of characters depends has been substantiated by studies of the structure of sexual cells. The purity of the gametes is evidently linked with the nucleus of the cells of a plant. During ordinary cell division the nucleus breaks into chromosomes and each cell possesses a definite number of chromosomes only. The number of chromosomes is a fixed number in each kind of plant Inasmuch as the chromatin threads forming the chromosomes split equally, so as to form twice the usual number of chromosomes, and then become equally distributed between the two cells formed, we have every reason to conclude that chromosomes constitute the physical basis of heredity. It is also obvious that all the cells resulting from the ordinary mode of cell division must be alike so far as the chromosomes and nuclei are concerned. For the sake of convenience we may assume that there are eight chromosomes in the nucleus of a cell. Then all the cells formed by ordinary cell divisions would have the same number of chromosomes. All the cells in a plant body are of course derived from the zygote. And from what we know of the process of sexual reproduction, this zygote must contain eight chromosomes derived from the two parents. This number represents twice the number of chromosomes contained in each of the gametes. It is thus obvious that every cell of the plant body contains a double set of chromosomes, half of them being descended from the chromosomes introduced by one plant, whilst the other half from the second. In other words, the adult plant has in every cell of its body chromosomes, or hereditary material, derived from both of its parents.

Considering the fact that the gametes contain only half as many chromosomes as the cells of the plant body and that the number of chromosomes present in the ordinary cells is constant for each species, we have to conclude that there must occur a reduction in the number of chromosomes to one-half their former number during the formation of the gametes or at some one or other of the cell divisions leading up to their formation. In plants the reduction takes place during the formation of the spores, pollen grains and the ovules.

The cell division preceding the formation of pollen grains and ovules differs in some respects from the ordinary cell division. In the ordinary cell division the nuclear material

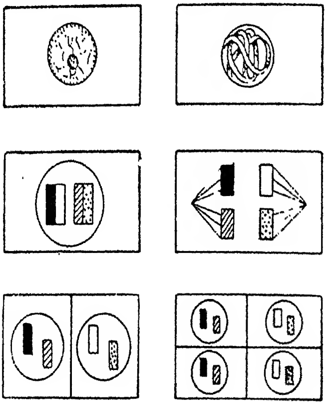


FIG. 484. Reduction division of cells (Diagrammatic).

is equally distributed between the two daughter cells and they are similar in every respect. The number of the chromosomes is the same and there is no reduction. But in the cell division which leads to the formation of pollen grains and ovules, the distribution of nuclear matter is such that each sex cell gets one set of complete chromosomes instead of the double set which ordinary cells of the plant possess. other words, the chromosomes cannot be considered to identical in all the daughter cells resulting from the divisi

The nuclear matter that enters one daughter cell may contain some material quite different from that contained in the nuclear matter entering the other daughter cell.

In reduction division also the nuclear matter breaks into threads, and a series of changes take place leading to the formation of a number of short stout chromosomes, but the number of these chromosomes is only half of the number of the chromosomes found in the tissue cells of the same plant. These chromosomes are paired ones. They all come to the equatorial plate and then the separation of the chromosomes takes place. The separation is not the longitudinal division of the same chromosomes into halves, but separation of entire chromosomes. So each daughter cell receives only half as many chromosomes as are found in the cells of the other parts of the same plant. After this separation and reduction of chromosomes, the further division leading to the actual spores is ordinary cell division.

This reduction division leading to the formation of sex cells with only half the number of chromosomes has a most important physiological significance. Supposing the sex cells that fuse to form the zygote contained the full number of chromosomes, then the zygote will have double the number of the chromosomes and in the next generation a further doubling must occur, and if this goes on there will result a piling up of the chromosomes. The object of reduction division is thus seen to be to prevent the enormous multiplication of chromosomes and to keep the number constant.

If the ordinary cells of the plant body contain eight chromosomes, the pollen grains and the ovules have only four. It is believed that the four chromosomes passing into the ovules or the pollen grains do not all carry identical characters. Some pollen grains and ovules may have in their chromosomes factors not found in the chromosomes of others and *vice versa*. In the illustrative example we have been considering, the pollen grains may carry in the chromosome either the yellow or the green character and not both, and so also the ovule. When fusion occurs between the pollen grains and the ovules the resulting zygotes will have eight chromosomes and these eight will have pure

yellow, pure green, or a mixture of yellow and green according to the nature of the combination. On a little reflection it will be obvious that these are the only possible combinations. If the ovule and the pollen both contain the yellow factor in the chromosomes the new seed will have yellow cotyledons. Similarly, if the chromosomes of both contain the green factor, the resulting seeds will have green cotyledons. In both these cases the zygotes are homozygous. Instead of the same kind of chromosomes uniting, some containing yellow and some containing green may come together in the zygote thus making it heterozygous. In this case the seeds formed will have only yellow cotyledons. Out of every four chances, there are two chances for dissimilar unions giving rise to two heterozygotes and only one for similar unions giving rise to homozygotes. So that out of four combinations taking place at random, there would be one homozygote for yellow, one homozygote for green, and two heterozygotes for yellow and green, and this is exactly Mendel's ratio. Thus we see that the Mendelian conception of segregation and purity of gametes has a physical basis.

Mendel was not satisfied with studying only one pair of characters. Having ascertained the behaviour of single pairs of contrasting characters through several generations, he next took up the study of two or more pairs of such characters, to see how they behave in respect to each other. For example, we may consider the results he obtained by crossing a pea plant producing round seeds with yellow cotyledons with another bearing wrinkled seeds with green cotyledons. As a result of this crossing he had only round seeds with yellow cotyledons. The characters wrinkledness and green colour did not appear in any of the seeds of the first crossing. On self-fertilizing the individuals of the first generation, four distinct types of seeds appeared in the fruits formed. They were (1) round seeds with yellow cotyledons, (2) round seeds with green cotyledons, (3) wrinkled seeds with yellow cotyledons, and (4) wrinkled seeds with green cotyledons. Thus it is obvious that yellow and green form a pair of contrasting characters and round and wrinkled another allelomorph, the characters yellow and round being dominant. As there are only two pairs of characters, the

possible combinations are only four. It must also be remembered that each of these pairs of allelomorphs behaves independently of each other. When the proportion to one another of the seeds produced by the hybrid plants after self-fertilization was considered, it was found to be thus :—

Nine round yellow seeds; three round green seeds: three wrinkled yellow seeds: one wrinkled green seed.

Out of these sixteen seeds the one wrinkled green seed bred true and out of the nine round yellow seeds only one bred true. The rest of the seeds were not pure, as they began to split. The combinations and the number of individuals in each combination occurring in the second generation are really in accordance with the general principles of combinations. To make these points clear we should consider all the combinations in detail. Let us represent the pairs of allelomorphs by letters, using a capital letter for the dominant one and a small letter for the recessive. Then the combinations of the pair would be RR+2Rw+ww and of the other YY+2Yg+gg, when we consider allelomorphic pairs separately.

When these two combine we obtain the following combinations :—

(YY + 2Yg + gg) (RR + 2Rw + ww) = RRYY + 2RRYg + RRgg + 2RwYY + 4RwYg + 2Rwgg + wwYY + 2wwYg + wwgg—i.e., 16 combinations.

Since the dominants obscure the recessives we shall have :—

9RY + 3Rg + 3wY + wg.

Thus we see that when two pairs of contrasting characters are concerned in crossing the combinations are four and number of individuals is sixteen and the proportion is 9 : 3 : 3 : 1.

In the hybrid individuals the gametes would be, RY, Rg wY, wg male and female, and the possible combinations are shown in the diagram below.

The nine combinations that are in the white squares would be alike in external appearance and all of them would have round seeds with yellow cotyledons. This is because

both the dominant characters R and Y occur in the combination. Out of these nine only one RRYY has pure dominants, i.e., homozygous and this will breed true. The remaining eight are heterozygous.

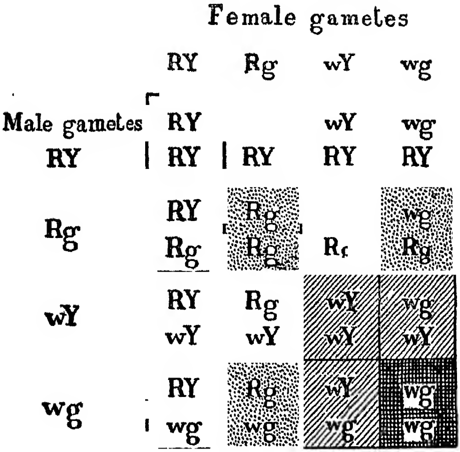


FIG. 485.

The three RgRg, Rgwg, Rgwg found in the squares with dots would have round green seeds R being dominant over w. The character Y is absent.

The three wYwY, wYwg, wYwg found in squares hatched with oblique lines would be wrinkled yellow seeds, Y being dominant over g. The character R is absent.

One wgwg in the square hatched with crossed lines is a wrinkled green seed. Both R and Y are absent. This is homozygous.

The two parents, round yellow and wrinkled green, were crossed and as a result of this two new varieties, namely, round green seeds and wrinkled yellow seeds have been formed.

As an example involving three pairs of contrasting characters we may consider the crossing of pea plants bearing round seeds with grey brown seed coats and yellow cotyledons with pea plants having wrinkled seeds with white seed coats

and green cotyledons. In this case also Mendel found that the pairs of contrasting characters behaved independently of each other, and that the combinations in the second generation were of many kinds. When three pairs of characters are involved in the crossing, theoretically, there must be in the second generation 64 individuals and 8 types of combinations. The details can be made out from the diagram given below. In the diagram, 'R' stands for round, 'Y' for yellow, 'Br' for grey brown, 'w' for wrinkled, 'g' for green, and 'al' for white; capital letters for dominant and small for recessive.

Male

Female	RY Br	RY al	Rg Br	wY Br	Rg al	wY al	wg Br	wg al
RY Br	RY Br 1 RY Br	RY al 1 RY Br	Rg Br 1 RY Br	wY Br 1 RY Br	Rg al 1 RY Br	wY al 1 RY Br	wg Br 1 RY Br	wg al 1 RY Br
RY al	RY Br 1 RY al	RY al 2 RY al	Rg Br 1 RY al	wY Br 1 RY al	Rg al 2 RY al	wY al 2 RY al	wg Br 1 RY al	wg al 2 RY al
Rg Br	RY Br 1 Rg Br	RY al 1 Rg Br	Rg Br 3 Rg Br	wY Br 1 Rg Br	Rg al 3 Rg Br	wY al 1 Rg Br	wg Br 3 Rg Br	wg al 3 Rg Br
wY Br	RY Br 1 wY Br	RY al 1 wY Br	Rg Br 1 wY Br	wY Br 4 wY Br	Rg al 1 wY Br	wY al 4 wY Br	wg Br 4 wY Br	wg al 4 wY Br
Rg al	RY Br 1 Rg al	RY al 2 Rg al	Rg Br 3 Rg al	wY Br 1 Rg al	Rg al 5 Rg al	wY al 2 Rg al	wg Br 3 Rg al	wg al 5 Rg al
wY al	RY Br 1 wY al	RY al 2 wY al	Rg Br 1 wY al	wY Br 4 wY al	Rg al 2 wY al	wY al 6 wY al	wg Br 4 wY al	wg al 6 wY al
wg Br	RY Br 1 wg Br	RY al 1 wg Br	Rg Br 3 wg Br	wY Br 4 wg Br	Rg al 3 wg Br	wY al 4 wg Br	wg Br 7 wg Br	wg al 7 wg Br
wg al	RY Br 1 wg al	RY al 2 wg al	Rg Br 3 wg al	wY Br 4 wg al	Rg al 5 wg al	wY al 6 wg al	wg Br 7 wg al	wg al 8 wg al

27 RY Br + 9 RY al + 9 Rg Br + 9 wY Br + 3 Rg al
+ 3 wY al + 3 wg Br + wg al

FIG. 486.

The number of types and the ratios in which each will appear for any number of pairs of characters can be determined by the algebraic formula $(a+b)^n$ where $a = 3$, and $b = 1$ and n stands for the number of pairs of characters. When

the pair is one the types are two and the total number of individuals is 4. If the pairs are 2, then

$$(3+1)^2 = 3^2 + 2 \cdot 3 \cdot 1 + 1 = 9 + 3 + 3 + 1 = 16.$$

Similarly

$$\begin{aligned}(3+1)^3 &= 3^3 + 3 \cdot 3^2 + 3 \cdot 3 + 1 \\ &= 27 + 9 + 9 + 9 + 3 + 3 + 3 + 1 = 64.\end{aligned}$$

$$\begin{aligned}(3+1)^4 &= 3^4 + 4 \cdot 3^3 + 6 \cdot 3^2 + 4 \cdot 3 + 1 \\ &= 81 + 27 + 27 + 27 + 27 \\ &\quad 9 + 9 + 9 + 9 + 9 + 9 \\ &\quad 3 + 3 + 3 + 3 \\ &\quad + 1 = 256.\end{aligned}$$

If the number of combinations alone are to be estimated then we may use the formula $x = 2^n$, where x stands for the number of combinations and n for the number of pairs of characters. If $n = 2$, then $x = 2^2 = 4$; if 3 then $x = 2^3 = 8$ and so on.

Mendel's experiments were practically confined to the pea plants and consequently he met with only simple conditions of inheritance. Recent investigators have not only verified repeatedly Mendel's laws in many plants, but also have observed many new situations not known to him. In fact there has been a great extension of our knowledge in the field of heredity, as this knowledge has considerable bearing on breeding work.

Every investigator observes the character of the plant and tries to find out which of them do mendelize, as a preliminary step for further work. For example, Biffen found in wheat plants that beardless ear was dominant to bearded ear, red grain to white grain and felted glumes to glabrous glumes. In the paddy plant Parnell has noticed several characters that are allelomorphs. When ordinary paddy with short outer glumes was crossed with a variety of paddy with long outer glumes the short glumes were dominant to long outer glumes. Other contrasting pairs of characters that were found are these,—Blackish-brown glumes of Pisini variety dominant to golden glumes of Ponkambi samba; piebald gold glumes of Garudan samba to gold glumes of Ponkambi samba; purple pigmentation in tips of glumes or axil of the leaf sheath to absence of pigmentation; purple internode to green internode; red rice of Borumuruthagna bhatta to white rice of Sada samba.

According to the views of Mendel both the dominant and recessive characters are due to two distinct factors. Certain facts have been observed which makes this view rather doubtful. In the course of his work, East came across two strains of maize, one with starchy grains and another with sweet grains. He found both of them homozygous by self-fertilizing them. When he crossed these two varieties he obtained a hybrid that gave results in conformity with Mendel's laws. That is to say all the grains formed after crossing were starchy grains, but in the grains raised from the crossed grains by self-fertilization both starchy and sweet grains appeared in the proportion 3 : 1 or 1 : 2 : 1. The strain with starchy grains is evidently able to convert all the sugar into starch, whereas the other one with sweet grains is unable to do so. Thus it is obvious that the gametes of the strain with starchy grains contain a determiner which leads to starch formation and this determiner is absent in the gametes of the sweet strain. So the dominance of a character over another is not a question of two contrasted factors, as was held by Mendel, but a question of the presence or absence of a factor. The view that the contrasting characters are due to two distinct determiners has lost its hold. The view now generally held is that dominance is the presence of a factor and the absence of it is recessiveness. This theory of presence and absence of a factor explains several cases which could not be explained satisfactorily by the Mendelian conception of dominance.

In most cases, if not in all, observed by Mendel one of the contrasting characters was found always to be dominant to another in all the individuals of the first generation, and in every three out of four of the individuals in the second generation. Many instances have been observed in which the individuals of the first generation derived by crossing two different plants did not show dominance, but they had some intermediate character or new characters not found in either of the parents. For example, a variety of paddy with straw coloured glumes was crossed with another variety with golden coloured glumes, and the hybrid plants of the first generation bore patchy golden colour in the glumes. Two strains of white maize when crossed gave a hybrid generation that bore purple grains in their cobs.

In several cases of crossing of plants the conditions found in F2 generations were not in strict conformity with Mendelian laws. A pea plant having smooth seeds with grey or brownish grey seed coats was crossed with another plant producing seeds with white seed coats. The F1 hybrids had purple dots on a grey ground in the seed coat. In the second generation on self-fertilizing there appeared purple-grey seeds, grey seeds and white seeds in the proportion 9 : 3 : 4. This is really a case with two pairs of allelomorphs, namely, (1) purple and no purple and (2) grey and no grey. So the ratio must be as shown below :—

$$9\begin{Bmatrix}\text{Purple}\\\text{Grey}\end{Bmatrix} : 3\begin{Bmatrix}\text{No purple}\\\text{Grey}\end{Bmatrix} : 3\begin{Bmatrix}\text{Purple}\\\text{No grey}\end{Bmatrix} : 1\begin{Bmatrix}\text{No purple}\\\text{No grey}\end{Bmatrix}$$

For the appearance of purple colour the grey factor is necessary. Of the two parents selected for crossing one parent had only the grey factor and the other had no grey factor but had one for purple. The white parent which contained the purple had no grey factor in it and so the purple colour did not appear in the seed coat. In the second generation the three plants with purple factor and no grey as well as the single individual with no grey and no purple must appear as white and hence the proportion is 9 : 3 : 4.

Another interesting case in which the proportion of the individuals in the second generation looks different from the usual Mendelian ratio is that of Bateson's sweet peas (Lathyrus odoratus). He crossed two varieties of sweet pea having white flowers and all the plants of F_1 generation produced when grown purple flowers. When the second generation was raised from the first the individuals that appeared consisted of a mixture of plants some purple, some red and others white. The proportion of coloured flowers to white flowers was found to be 27 purple : 9 reds : 28 whites, i.e., 36 coloured : 28 white. This is really 9 : 7. From the appearance of the colour in the individuals of the F_1 generation it is obvious that in the two white parents there must be factors which when kept separate do not produce any colour but when brought together produce colour. Each of the parents seems to have a complementary factor. When these two complementary factors were brought together red colour appeared. In addition to red flowers, purple flowers also

appeared in some individuals of the second generation raised from the first generation. This is believed to be due to the presence of another factor in one of the white parents. When all the three complementary factors are present the flowers are purple; if two they are red, and if only one they are white. The proportion of the individuals of the second generation looks as though three pairs of allelomorphs are concerned. Then in the second generation we ought to have 64 individuals and 8 combinations if three pairs of characters are concerned. If we represent the three pairs of contrasting characters by the letters C B R—c b r, capital letters for dominance and small for recessiveness, then there will be :— 27 CRB+9 CRb+ 9 CrB+9 cRB+3 Crb+3 cRB+ 3 crB+ 1 crb. That is, 27 purples+9 reds + 9 whites + 9 whites + 9 whites + 1 white = 36 coloured : 28 white = 9 coloured : 7 white. This is exactly what Bateson obtained in F_2 generation when he crossed the two white varieties of sweet peas. A parallel case was observed by Parnell in paddy. He crossed Garudan samba and another variety 614N, both being green in all their parts without any purple pigmentation. The individuals in F_1 generation had purple colour in their internodes and glume tips. The F_2 generation raised from F_1 by self-fertilization, gave 9 plants with purple colour in the internodes and glume tips and 7 plants with no purple colour in the internodes and glume tips, but with green colour in these parts.

Another interesting condition in which the contrasting characters are coupled with one another and transmitted together has also been observed. Emerson in his experiments with maize observed a case of this sort. When a maize without any colour in its grain or cob was crossed with a variety of maize with red cobs or red grains, in the individuals of the F_2 generation red cobs and red grains occurred together and not separately.

The main conclusions and discoveries of Mendel may be briefly stated as follows :—

(1) He viewed a plant as an aggregate of characters and found that characters do not blend and that each character behaved as a unit and separates completely from one another,

(2) In the case of two contrasting characters one was found to be dominant and the other recessive.

(3) The gametes or the sexual cells are always pure and they contain the gene or factor for only one of a pair of allelomorphs, and even if the genes for both the characters enter the zygote very soon segregation takes place in the sexual cells of the F1 generation when they form their pollen grains and ovules.

(4) The offspring of a hybrid consist of dominants and recessives in the ratio of 3 : 1 ; the recessives and one-third of the dominants breed true, while two-thirds of the dominants breed as hybrids producing dominants and recessives and again in the ratio of 3 : 1.

(5) Even when a number of allelomorphs are concerned each pair behaves independently, and further all combinations of characters according to the mathematical laws of combination can be obtained.

The value of the discoveries of Mendel is very great. All the truths established by him are of enormous importance to breeders. His laws enable the breeders to know what the effects of crossing would be and to interpret results which were not understandable. Owing to the discovery of the segregation of gametes we now know that, in the second generation of hybrids, individuals that are perfectly pure occur in definite proportions, and that purity of plants in respect to a character does not depend upon a long series of selection as was formerly the notion. Characters found in different plants may be combined in one plant, taking advantage of the fact that contrasting characters behave independently.

We cannot conclude this subject better than by showing a few instances of the practical application of Mendel's discoveries. Several improvements have been effected in cereals by following the new method of work in America, Europe and India. In the case of wheat Biffen saw two varieties one with hard grain but with poor yield and another with heavy yield and soft grain. He crossed both these varieties and obtained a hybrid which had hard grains and with good yield. A variety of wheat with white chaff was very much in demand but it was liable to rust. Another variety having red chaff with immunity for rust was also observed. By crossing

these two plants Biffen obtained a variety of wheat with white chaff and immune to rust. Thus he succeeded in bringing together in one plant two qualities found separately in two plants. When a Cambodia cotton plant having monopodial branches and fuzzy seed was crossed with a Bourbon cotton plant having sympodial branches, the hybrids of the first generation had monopodial branching and naked seeds. When the second generation was raised from the first generation, there appeared four types of plants, viz., (1) plants with monopodial branching and naked seeds, (2) plants with monopodial branching and fuzzy seeds, (3) plants with sympodial branching and naked seeds and (4) plants with sympodial branching and fuzzy seed and the ratio was 9 of No. 1 : 3 of No. 2 : 3 of No. 3 : 1 of No. 1. The first and the fourth are new combinations.

Thus it is clear that new types of plants may be produced by the recombination of pre-existing characters. If the characters that are to be recombined are recessive, one can very easily get the combination by crossing twice, and the plant having the combinations would breed true on self-fertilizing. But when the characters to be recombined constitute a mixture of dominants and recessives, the work is not so easy. Several crossings and selections would be necessary. Another advantage of crossing, in addition to the combinations, is the increase of vigour in the offspring or hybrids. Darwin mentions that cabbage plants raised by crossing were 3 times the weight of those obtained by self-fertilization. Maize, pumpkins and tomatoes are other plants which produce more vigorous offspring when crossed.

SUPPLEMENT

GYMNOSPERMS

THE Spermaphytes consist of the two groups, Angiosperms and Gymnosperms. In the former the ovules are enclosed in a case, whereas in the latter they are naked without any covering. Angiosperms form the chief part of the present day vegetation, but the Gymnosperms form but an insignificant portion of the flora. Cycas, Podocarpus and Gnetum are the only genera of this group met with in a wild state in South India. These belong respectively to the families, Cycadaceæ, Coniferæ and Gnetaceæ. Some species of Pinus, Cupressus and Araucaria, all belonging to the family Coniferæ, are grown in some places as ornamental trees.

CYCADACEÆ.

The tree *Cycas circinalis*, L., occurs in the forests of South India, and it is also grown in gardens and conservatories. A

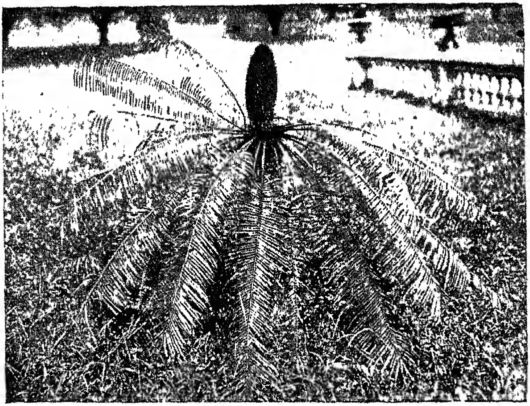


FIG. 487. Male cone of *Cycas circinalis*, L.
(From a photograph by Mr. M. O. Parthasarathi Ayyangar, M.A., Madras.)

well-grown Cycad tree will be about fifteen feet high with a of beautiful, leathery, green leaves. The leaves have

strong mid-ribs and persist for a year or two, and are replaced periodically by successive crowns of leaves. In certain respects, this tree bears a superficial resemblance to a palm, while in some characters it is suggestive of ferns. The trunk or stem is erect, not generally branched, and covered externally by an armour of leaf bases.

FIG. 488. Female cone of *Cycas circinalis*, L.
(From a photograph by Mr. M. O. Parthasarathi Ayyangar, M.A., Madras.)

The leaves are long and vary in length from four to nine feet, according to the stage of development and vigour of the tree. The leaf stalk is about a foot and a half, and it bears

short, distant spines to almost near the base of the blade. The leaf is pinnately compound, with long, linear, stiff, one-nerved shining leaflets of about quarter of an inch width. In young leaves the leaflets are circinnately folded as in the fronds of ferns. (See fig. 489.)

Being a seed plant it produces pollen and ovules, but on different trees (diœcious). After pollination and fertilization the ovules develop into seeds. The pollen is formed in the unilocular anthers, found in groups of three to five, on the lower surfaces of brownish leathery scales that are closely aggregated, so as to form a cylindric ovoid body or **cone.** When fully mature the cones are about a foot and a half long. The antheriferous scales are really modified leaves bearing pollen grains or microspores, and hence they are called **microsporophylls.** (See fig. 490.)

The ovules also are borne by modified leaves called **megasporophylls**, which are considerably larger than the

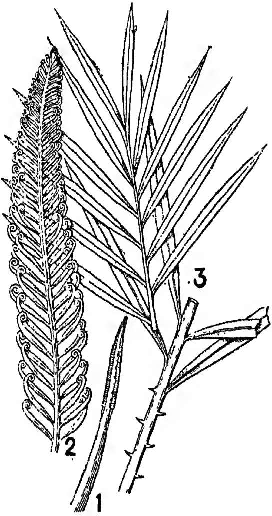


Fig. 489. *Cycas circinalis*, L. 1, Very young leaf; 2, young leaf; 3, basal and apical portions of a mature leaf.

microsporophylls. The megasporophyll when fully mature is about a foot long, and looks very much like reduced leaves. The upper end of the sporophyll bears a number of small leaflets, but in the lower portion, in the place of leaflets, there are ovules. The megasporophylls occur in groups at the summit of the stem, but do not form compact cones. They surround the growing point of the stem.

The ovules occur singly, in the places of the leaflets, and there are three to five pairs of ovules in each megasporophyll. The ovule consists of a nucellus invested by a single integument. There is also a micropyle in the integument leading into the interior to the nucellus. Just above the nucellus there is a cavity spacious enough for the lodging of a few

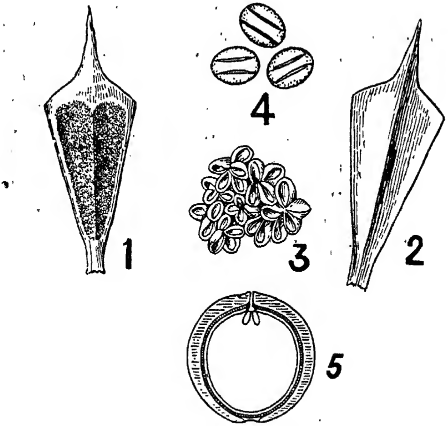


FIG. 490. Antheriferous scales and ovule of *Cycas circinalis*. 1, 2, Antheriferous scales, front and back view; 3, anthers; 4, pollen grains; 5, ovule, showing the endosperm, archegonia and the integument.

pollen grains. This cavity is called the pollen-chamber. Within the nucellus the endosperm is formed before fertilization, and it corresponds to the prothallus in the megaspore of Selaginella. At the top of the endosperm three or four archegonia are formed. An archegonium consists of a neck

made up of a few cells and a venter containing a large egg-cell, the largest in the vegetable kingdom.

The pollen is wind borne in this tree, and by chance some pollen grains find their way into the pollen-chamber. The pollen grains germinate, form some tubes which absorb food from the remnants of the nucellus. In addition to these absorbing tubes, other tubes larger than these arise from the pollen grains, and these tubes carry the generative cell further down into the pollen chamber. The generative cell passes down to the extremity of the tube and becomes divided into two sperm-cells. The sperm-cells are very interesting bodies. They bear a large number of cilia and so they are capable of motion. (See fig. 491.) As soon as the pollen tube reaches the archegonia it empties its watery contents. The sperm-cells get into the archegonia by moving through this water. Afterwards fertilization is effected and the embryo is formed.

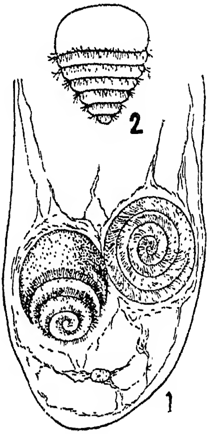


FIG. 491. Sperm-cells of *Cycas revoluta.* 1, Pollen tube with two sperm-cells; 2, sideview of a sperm-cell.—(After Ikeno and Coulter.)

Cycads are the simplest and the lowest type of all the living seed-plants. It is the only plant which produces naked seeds without developing a cone or a flower. While it

possesses certain characteristics of the seed-bearing plants, in many respects it resembles a Selaginella. The formation of multiciliate sperm-cells, the development of the gametophyte within the megaspore, the circinnate vernation of the leaflets and the sporophylls, show the relationship of the Cycads to the heterosporous forms of Pteridophyta. The development of the seed and the gametophyte remaining attached to the sporophyte until the formation of the embryo are forward steps towards spermatophytes. The presence of the pollen-chamber below the micropyle is a special character of the Gymnosperms.

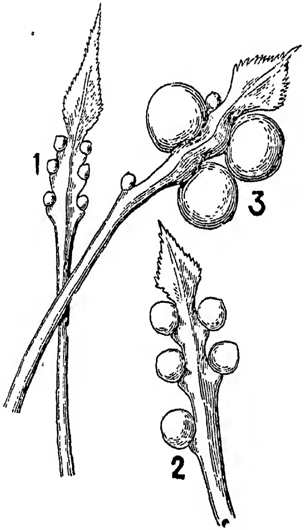


FIG. 492. Megasporophylls of *Cycas circinalis*. 1, Young one; 2, 3, older ones.

Although Cycads are rare now, in past ages they figured more largely in the flora of the earth.

CONIFERÆ

The two Pines, *Pinus longifolia*, Roxb. and *P. excelsa*, Wall., belonging to Coniferæ, occur in South India in parks

and gardens. They are lofty symmetrical trees with a characteristic pyramidal shape. The main stem and their branches retain their apical buds and so they are capable of growing in length to any extent. The main trunk is quite straight and it can be traced from the ground to the top of the tree. The lower branches are longer and they get gradually shorter towards the top of the tree. It is in consequence of this peculiarity, that the pine trees assume pyramidal shapes especially when they grow in open places.

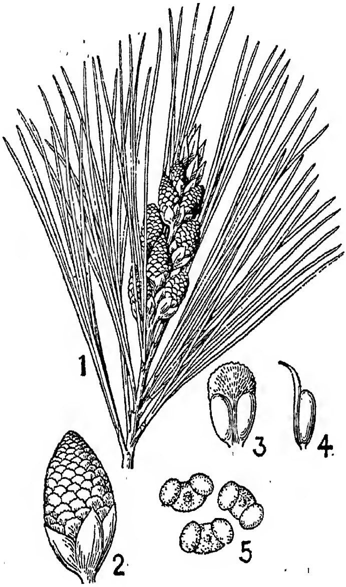


FIG. 493. Male cone-bearing branch of *Pinus excelsa*, Wall. 1, Branch with leaves and male cones ; 2, a male cone ; 3, 4, staminal scales ; 5, pollen grains

There are two kinds of branches, namely, long branches and dwarf branches or spur shoots. The long branches grow in length considerably due to the activity of the terminal bud. On these long branches occur only brown scale-like leaves.

The dwarf branches arise from the axils of the scale-leaves and they remain very short, never exceeding a fraction of an inch. Each spur shoot bears at its apex a cluster of needle-shaped green leaves. In Pinus longifolia the cluster consists of three leaves and in P. excelsa it may have five to eight leaves.

Leaves are of two kinds, namely, the scale-leaves borne by the long branches and the foliage leaves found at the ends of spur-shoots. The base of the cluster of leaves is always sheathed by thin membranous scales of the terminal bud of

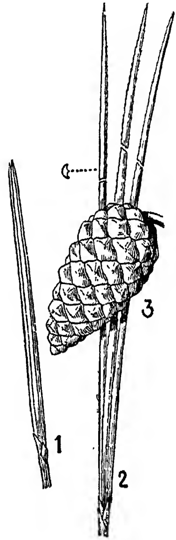


FIG. 494. Female cone and leaves of *Pinus longifolia*, Roxb. 1, 2, Leaves ; 3, female cone.

the dwarf branch. Pine leaves persist on the tree for several years. Therefore, this tree is never bare of leaves although each year some of the older leaves drop off. With the fall of the cluster of leaves, the spur-shoot dries up.

The reproductive bodies, pollen and ovules, are borne by scales which are sporophylls. Both **microsporophylls** and **megasporophylls** are aggregated together in **cones**. Both the cones occur on the same tree. The male or staminate cones are small cylindrical bodies, not exceeding half an inch in length. They occur in clusters. Each cone consists of an axis bearing scales arranged in spirals. There are two sporangia or anthers on the lower side of every scale. The female cones also consist of a central axis with spirally arranged scales and each scale bears two ovules. Both the staminate and the ovule-bearing cones are modified branches. The female cones occur singly and not in clusters.

The pollen grains are queer-looking objects. They are provided with two air-sacs one on each side of a grain. In a fully mature pollen grain, four cells can be made out. They are two prothallial cells, mother cell of the antheridium and a tube cell. The two prothallial cells are not always clear, sometimes disorganized remnants only being visible.

The megasporophyll has two ovules. Each of these ovule-bearing scales is believed to be two sporophylls fused together. The ovule or the megasporangium consists of the nucellus invested by an integument. At the apex of the ovule there is a micropyle, leading to a cavity below (pollen-chamber). Within the nucellus endosperm is formed and a remnant of the necellus persists at the top near the pollen-chamber. The endosperm corresponds to the prothallus formed in the megaspore of Selaginella.

Pollen is produced in abundance. The air-sacs facilitate the floating of the pollen grains in large numbers in the air. Consequently some of them get into the female cones and reach the pollen chambers. When the female cones are ready for pollination (lodging of the pollen grains in the pollen-chamber) the scales gape open. After pollination the scales close up without leaving any passage.

The pollen grain begins to germinate in the pollen-chamber and forms a tube at first with which it absorbs food material from the remnants of the nucellus. Later on another large tube is formed which goes deeper into the pollen-chamber. At this stage there are only two cells in the grain, namely, the antheridial mother cell and the tube cell. The

latter descends into the end of the pollen tube, and the former divides into a stalk-cell and a generative cell. While these changes are going on, there will be formed in the prothallial tissue or the endosperm four or five archegonia. The pollen tube reaches the archegonia and by bursting pours in its contents and the generative cell now divided into two sperm-cells. One of the sperm-cells, now reduced to a nucleus, fuses with the egg-cell in the archegonium. After this fusion the embryo is formed.

Soon after the lodging of the pollen grains in the pollen-chamber, the micropyle closes, by the growth of the integument in thickness, and the scales begin to grow and close up. In some species of Pines the scales secrete a resinous substance, which forms an effective barrier for water. The cones increase in size very much after pollination. The processes of pollen germination and fertilization are of longer duration in Pines than in other seed-plants. The formation of the seed and the ripening of the cones are also prolonged for nearly a year.

The Cycads and the Pines clearly show that the Gymnosperms have affinities with heterosporous Pteridophytes on the one side and with the Angiosperms on the other.

APPENDIX I

ENGLER'S SYSTEM OF CLASSIFICATION

As this system of classification is now being gradually adopted in all the universities and colleges a brief account of the system is appended.

MONOCOTYLEDONS.

1. Pandanales—Marsh herbs or trees. Infl. compound heads or spikes. Flowers uni-sexual, naked or with single or double perianth; perianth bract-like. Stamens and ovary 1 to indefinite.
2. Helobieæ—Aquatic or marsh plants. Flowers cyclic or spiral; perianth, 0, 1 or 2 whorls, both alike or differentiated into calyx and corolla; stamens 1 to indefinite; ovary 1 to indefinite, inferior or superior. Endosperm present.
3. Triuridales—Saprophytes. Flowers small, long stalked, bi-sexual or uni-sexual; perianth 3 to 8, petaloid; stamens 3, 4 or 6; ovary of many carpels, superior, with one basal ovule in each. Pericarp thick.
4. Glumifloræ—Usually herbs. Flowers without perianth; in the axils of glumes (bracts); ovary superior 1-celled and with 1 ovule.
5. Principes—Trees or climbers with palmate or pinnate leaves. Flowers regular, uni-sexual in compound spikes or spike-like racemes with spathes; perianth in two whorls of three; stamens 3, 6, 9 or indefinite; ovary 3-celled, with 1 ovule in each. Fruit berry or drupe.
6. Synanthæ—Palm-like herbs, shrubs or climbers. Flowers uni-sexual, male and female flowers alternating over surface of spike; male flowers naked or with thick short perianth and 6 to indefinite stamens; female flowers naked or with fleshy scaly perianth; ovary many celled with the carpels united and sunk in fleshy spike. Fruit multiple.
7. Spathifloræ—Herbs or shrubs, erect or climbing, stem usually sympodial. Flowers bi- or uni-sexual, naked or with perianth; single or double, in spadices enclosed by spathes.
8. Farinosæ—Herbs, rarely with stout stems. Flowers cyclic, di- or tri-merous; perianth in 2 whorls of 3; stamens 3 or 6, rarely 1; ovary superior 3 or 1. Endosperm mealy.
9. Lilifloræ—Herbs or shrubs. Flowers bi-sexual, tri merous; perianth 6; stamens 6; ovary superior 3. Endosperm fleshy or oily.

10. SCITAMINEÆ—Herbs, small or large. Flowers bi- or uni-sexual zygomorphic or asymmetric and tri-merous; perianth single or double; stamens 6, 5 or 1; ovary inferior, 3. Seeds arillate. Inflorescence with large petaloid bracts.
11. MICROSPERMÆ—Small or large plants. Flowers tri-merous; perianth of two distinct whorls; stamens reduced to a single anther; ovary inferior 3 or 1 loculed with many minute ovules.

DICOTYLEDONS.

I. Archichlamydeæ.

(Flowers naked, or with one or two whorls of perianth, and petals free very rarely united.)

1. VERTICILLATÆ—Trees. Flowers uni-sexual; male flowers in catkin-like spikes, consisting of a stamen with two bract-like perianth; female flowers in heads, consisting of a 2-celled ovary with 2 to 4 ovules in 1 cell, the other being empty.
2. PIPERALES—Herbs or shrubs. Flowers bi- or uni-sexual, naked, or with a single whorl of perianth; stamens 1 to 10; ovary 1 to 4, free or united.
3. SALICALES—Woody plants. Flowers, diœcious, naked and in spikes; stamens 2 to indefinite; ovary superior, 2, 1-loculed with many ovules on a parietal placenta.
4. GARRYALES—Woody plants with opposite evergreen leaves. Flowers in catkin-like panicles, uni-sexual; male with 4 perianth lobes, 1 to 4 stamens and female with a superior ovary 2 to 3, 1-locular and with 2 ovules.
5. MYRICALES—Woody plants. Flowers uni-sexual, naked; stamens 4 or 2 to 16; ovary superior, 2, uni-locular with 1 ovule.
6. BALANOPSIDALES—Woody plants. Flowers uni-sexual; male in spikes with one whorl of perianth; female with many bracts surrounding a superior ovary with 2 ovules.
7. LEITNERIALES—Woody plants. Flowers diœcious, in spikes. Male without perianth, stamens 3–12; female with superior ovary 1, and ovule 1.
8. JUGLANDALES—Woody. Flowers spiked, uni-sexual, with or without perianth; stamens 3 to 40; ovary inferior 2, 1-locular, with 1 ovule. Fruit drupe or nutlike.
9. BATIDALES—Seashore shrubs with opposite fleshy leaves and panicles of spikes. Flowers uni-sexual; male with a cup-like perianth and 4 stamens; female with ovary only. Fruit
10. JULIANIALES—Woody with alternate pinnate leaves, diœcious. Male flowers indefinite in dense panicles with 6 to 8 stamens; female flowers in fours in spikes, naked with ovary 1 and 1 ovule.
11. FAGALES—Woody, monœcious. Flowers in cymose spikes, with a double perianth, rarely naked; stamens opposite to the perianth; ovary 2 to 6, ovules 1 or 2.

12. URTICALES—Herbs, shrubs or trees. Inflorescence cymose. Flowers bi- or uni-sexual; stamens opposite perianth; ovary superior 1 to 2, with one ovule in each. Fruit drupe or nut. Perianth, 0, 1 or 2 whorls.
13. PROTEALES—Woody. Flowers bi- or uni-sexual, spikes or racemes; perianth petaloid; stamens opposite to, and adherent to the perianth; ovary superior 1.
14. SANTALALES—Herbs, shrubs or trees often parasitic. Flowers bi-sexual, perianth leaves all alike; stamens in 2 whorls; ovary superior 2 to 3, rarely 1, with one pendulous ovule.
15. ARISTOLOCHIALES—Flowers regular or zygomorphic, perianth petaloid, single rarely double; ovary inferior 3 to 6, with axile placentation or 1-locular with parietal placentations; ovules indefinite.
16. POLYGONALES—Herbs or shrubs, leaves ochreate. Flowers regular bi-sexual; perianth single or double; ovary superior unilocular with a single basal erect ovule.
17. CENTROSPERMÆ—Herbs. Flowers cyclic or spiral; perianth, single or double; stamens definite or indefinite; ovary superior 1 to many carpels, united or free, rarely inferior unilocular, with indefinite ovules.
18. RANALES—Herbs or shrubs. Flowers, spiral or spiro-cyclic; perianth rarely 0, 1 or 2 whorls; stamens indefinite; ovary superior 1 to many, usually free.
19. RHŒADALES—Herbs. Flowers in racemes, cyclic, regular or zygomorphic; perianth, 1 or 2 whorled; ovary superior 2 to many.
20. SARRACENIALES—Herbs; insectivorous. Flowers regular, cyclic to spiro-cyclic; perianth 1 or 2 whorls; stamens indefinite or definite; ovary superior 3 to 5; indefinite ovules on parietal or axile placentation.
21. ROSALES—Flowers cyclic, rarely spiro-cyclic; perianth of 2 whorls rarely 0, hypogynous to epigynous; stamens definite or indefinite; ovary with numerous ovules.
22. PANDALES—Flowers cyclic, diœcious; perianth of 2 whorls; ovary superior, 3; one pendulous ovule in each carpel. Fruit, drupe.
23. GERANIALES—Flowers 5. merous, naked or with 2 whorls of perianth; stamens various; ovary superior, 2 to 5, rarely more, separating when ripe; ovules 1 to 2 rarely indefinite.
24. SAPINDALES—Woody plants; as the last but ovule pendulous and reversed in position.
25. RHAMNALES—Flowers cyclic, sometimes apetalous. Stamens opposed to the petals, regular; ovary 2 to 5, with 1 to 2 ascending ovules in each.
26. MALVALES—Flowers cyclic, rarely apetalous, both calyx and corolla present; calyx 5 merous, valvate, stamens numerous or in 2 whorls and the inner branched; ovary 2 to indefinite, each with 1 to indefinite ovules.

27. PARIETALES—Flowers cyclic or spiro-cyclic; with both calyx and corolla, rarely apetalous; stamens and carpels indefinite; hypogynous to epigynous; carpels many, with parietal placentas, which may touch in the centre.
28. OPUNTIALES—Leafless succulents, thorny. Flowers bi-sexul, partly spiral, with both calyx and corolla; stamens indefinite on tubular axis; ovary 4 to indefinite, unilocular with numerous ovules on parietal placentas.
29. MYRTIFLORÆ—Herbs, shrubs or trees. Flowers bi-sexual, with both calyx and corolla, rarely apetalous; stamens in one or two whorls; ovary 2 to indefinite; united to axis, rarely 1, free.
30. UMBELLIFLORÆ—Flowers, cyclic, umbellate, with both calyx and corolla; stamens one whorled, epigynous; ovary inferior, 1 to 5 or indefinite, with 1, rarely 2, pendulous ovules in each.

II. Sympetalæ.

(Petals Usually United.)

1. ERICALES—Herbs or shrubs. Flowers bi-sexual, regular 4 to 5 merous. Corolla, united; stamens hypo- or epi-gynous rarely united to petals at base, obdiplostemonous, or whorl before corolla not developed; ovary 2 indefinite, before corolla when equal in number, superior to inferior.
2. PRIMULALES—Flowers bi- or uni-sexual, regular or zygomorphic, usually 5 merous (rarely 4 to indefinite); stamens epipetalous, 5; petals united; ovary superior to inferior, unilocular with 1 to indefinite ovules on basal or free central placentation.
3. PLUMBAGINALES—Herbs or shrubs. Flowers bi-sexual, 5 merous. Ovary 1 locule, with one ovule. Endosperm starchy.
4. EBENALES—Woody plants. Stamens in 2 or 3 whorls or in 1 whorl by abortion, rarely indefinite. Ovary, many and with axile placentation; ovules few or 1 in each locule.
5. CONTORTÆ—Herbs or shrubs, leaves opposite and exstipulate. Flowers 5 merous, rarely 2 to 6 merous, corolla tubular, rarely free or apetalous; stamens 5, epipetalous; ovary 2 loculed, superior.
6. TUBIFLORÆ—Herbs. Flowers, tetramerous, and isomerous if regular, but ovary less; if zygomorphic stamens less, epipetalous.
7. PLANTAGINALES—Herbs or shrubs. Flowers bi- or uni-sexual, 4 merous; stamens epipetalous; ovary superior, 2 celled, or 1 to 4, with 1 or few ovules in each.
8. RUBIALES—Herbs, shrubs or trees with simple opposite leaves. Flowers 4 or 5 merous, regular; ovary 1 or more locular; ovules 1 to many in each.

9. CUCURBITALES—Flowers uni-sexual, 5 merous. Stamens 5, free or united or each two united, or all five united in a central mass (Synandrium). Ovary inferior 3 carpelled and unilocular.
10. CAMPANULATAE—Herbs or shrubs. Flowers 5 merous; stamens in 1 whorl, and ovary with fewer carpels; anthers syngenesious; ovary superior or inferior; 1 celled with one ovule or many celled with more than one ovule in each cell.

Families described (in this book) grouped according to Engler's system :—

MONOCOTYLEDONS.

GLUMIFLORÆ—Gramineæ, Cyperaceæ.
PRINCIPES—Palmæ.
SPATHIFLORÆ—Araceæ.
FARINOSÆ—Commelinaceæ.
LILIFLORÆ—Liliaceæ, Amaryllideæ.
SCITAMINEÆ—Scitamineæ.
MICROSPERMÆ—(

DICOTYLEDONS.

I. Archichlamydeæ.

URTICALES—Urticaceæ.
CENTROSPERMÆ—Amarantaceæ, Aizoaceæ, Portulacacæ.
RANALES—Nymphæaceæ, Anonaceæ.
RHŒADALES—Capparideæ; Cruciferæ.
ROSALES—Leguminosæ.
GERANIALES—Geraniaceæ, Linaceæ, Rutaceæ. Meliacæ, Polygalaceæ Euphorbiaceæ.
SAPINDALES—Anacardiaceæ, Sapindaceæ.
RHAMNALES—Rhamnaceæ, Vitaceæ.
MALVALES—Tiliaceæ, Malvaceæ; Sterculiaceæ.
PARIETALES—Violaceæ.
MYRTIFLORÆ—Combretaceæ, Myrtaceæ.
UMBELLIFLORÆ—Umbelliferæ.

II. Sympetalæ.

EBENALES—Sapotaceæ.
CONTORTÆ—Apocynaceæ, Asclepiadeæ.
TUBIFLORÆ—Convolovulaceæ, Boragineæ Labiatæ, Solanaceæ, Scrophularineæ, Pedalineæ, Acanthaceæ.
RUBIALES—Rubiaceæ.
CUCURBITALES—Cucurbitaceæ.
CAMPANULATÆ—Compositæ.

APPENDIX II

LIST OF BOOKS FOR REFERENCE AND STUDY

1. GENERAL TEXT-BOOKS.

FITTING, JOST, SCHENCK AND KARSTEN—Strasburgher's Text Book of Botany—Fifth English Translation. Macmillan & Co., Ltd., London.

COULTER, BARNES AND COWLES—A Text Book of Botany for Colleges and Universities. American Book Company, New York,

KERNER AND OLIVER—Natural History of Plants, 2 vols. Blackie & Son, London.

VINES—Students' Text Book of Botany. Swan Sonnenschein, London.

GANONG—A Text Book of Botany for Colleges. Macmillan & Co., London.

BOWER—The Botany of the Living Plant. Macmillan & Co., London.

CAMPBELL--A University Text Book of Botany. Macmillan & Co. London.

CURTIS—Nature and Development of Plants. Henry Holt & Co., New York.

GAEGER—Fundamentals of Botany. P. Blakiston's Son & Co., Philadelphia.

DENSMORE—A General Botany for Colleges and Universities. Ginn & Co.

ATKINSON—A College Text Bock of Botany. Henry, Holt & Co., New York.

BERGEN AND CALDWELL—Practical Botany. Ginn & Co., Boston.

SMALL—Text Book of Botany for Medical Students. Churchill, London.

2. MORPHOLOGY AND HISTOLOGY.

GOEBEL—Organography of Plants. English Translation, Vols. I to III. Clarendon Press, Oxford.

GOEBEL—Outlines of Classification and Morphology of Plants—English Translation. Clarendon Press, Oxford.

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APPENDIX III

VERNACULAR NAMES OF PLANTS

	Tamil.	Telugu.
	A	
Abrus—		
precatorious, *L.* ...	Kunthumani ...	Guriginja.
Abutilon—		
graveolens, *W. & A.* ...	Thuthi ...	Thuthiribenda.
indicum, *G. Don.*	Do. ...	Do.
Acacia —		
arabica, *Willd.*	Karuvēl ...	Nallatumma.
concinna, *DC.*	Seekāi ...	Seekaya.
Farnesiena, *Willd.*	Pee Vēlan ...	Kamputumma.
leucophlœa, *Willd.*	Vel Vēlan ...	Tellatumma.
planifrons, *W. & A.*	Kodaī Vēlan ...	Buddatumma.
Acalypha—		
indica, *L.*	Kuppaimeni ...	Kuppinta or Muripindi.
Achyranthes—		
aspera, *L.*	Nāyurivi ...	Uttarēni.
Ægle—		
Marmelos, *Corr.*	Bilvam ...	Bilvamu or Marēdu.
Ærua—		
lanata, *Juss.*	Poolai ...	Pindichettu.
Agave—		
americana, *L.*	Kaththāzhai ...	Bonthrākāsi or kiththanāra.
Ailanthus—		
excelsa, *Roxb.*	Peemaram or Perumaram.	Pee Vēpachettu
Albizzia—		
Lebbek, *Benth.*	Vāgai ...	Dirisana or Sirishamu.
Allium Cepa, *L*—		
(The onion)	Vengāyam ...	Yerragadda.
sativum, *L.* (The garlic) ...	Vellaipūndu ...	Tellagadda.
Allophylus—		
Cobbe, *Bl.*	Amalai ...	Eravālu.

	Tamil.	Telugu.
Alstonia—		
scholaris, *Br.*	Ezhilaippālai .	Edākulapāla.
Alternanthera—		
sessilis, *Br.*	Ponnānganni ...	Ponaganti.
Amarantus—		
gangeticus, *L.*	Thandukīrai ...	Kāmulu or Dantu.
spinosus, *L.*	Mullukīrai ...	Mullathōtakūra.
virdis, *L.*	Kuppaikīrai ...	Chilakathōtakura
Amoora—		
Rohituka, *W. & A.*	Semmaram ...	Sevamānu.
Amorphophallus—		
campanulatus, *Bl.*	Kārākaranai ...	Tīyakandha.
Anacardium—		
occidentale, *L.* (Cashewnut).	Minthiri ...	Muntha mamidi, or Jidi māmidi.
Ananas—		
sativus, *Schult.*	Annāsi	Anāsa.
Andrographis—		
echioides, *Nees.*	Gopurantāngi ...	...
Andropogon—		
Sorghum, *Brot.*	Chōlam	Jonna.
Anisomeles—		
malabarica, *Br*	Palampāsi ...	...
Anona—		
reticulata, *L.*	Rāmaseetha ...	Rāmaseetha.
squamosa, *L.*	Seetha	Seetha
Arachis—		
hypogæa, *L.*	Vērkadalai ...	Vērusanaga.
Areca—		
Catechu, *L.*	Pākku or Kamugu.	Poka.
Argemone—		
mexicana, *L.*	Brammadandu.	Dattūri.
Aristolochia—		
bracteata, *Retz.*	Aduthinnāpālai.	Gādathigada para.
Artocarpus—		
integrifolia, *L.f.* (The Jack)	Pilā	Panasa.
Asparagus—		
racemosus, *Willd.* ..	Thannirmuttān-kizhangu.	Challagadda chettu.
Avicennia—		
officinalis, *L.*	Kandal	Mada.

	Tamil.	Telugu.
Azadirachta— indica, *A. Juss.*	Vēmbu	Vēpa

B

	Tamil.	Telugu.
Bassia— longifolia, *L.*	Iluppai	Ippa.
Bauhinia— tomentosa,	Tiruvātti	Adavi mandāra
Benincasa— cerifera, *Savi.*	Kalyāna-pūshani.	Buditha or pulla gummidi.
Berrya— Ammonilla, *Roxb.*	Tirukanāmaram.	Saraladevadāru.
Boerhaavia— repens, *L.*	Mūkaratai	...
Bombax— malabaricum, *DC.*	Mulilavan	Konda Booraga.
Borassus— flabellifer, *L.*	Panai	Thāti.
Boucerosia— umbellata, *W. & A.*	Kallimulayān	...
Brassica— juncea, *HK. f. & T.*	Kadugu	Āvālu.
Bryophyllum— calycinum, *Salisb.*	Ranakalli	...
Buchanania— angustifolia, *Roxb.*	Kāttumā	Sāra.
latifolia, *Roxb.*	Sārappāruppu	Chāra.

C

	Tamil.	Telugu.
Cadaba— indica, *Lamk.*	Vizhuthi	...
Cæsalpinia— pulcherrima, *Sw.*	Mayilkonnai	Turāi.
Cajanus— indicus, *Spreng.*	Thuvarai	Kandhi.
Calamus— Rotang, *L.*	Perambu	...
Calophyllum— inophyllum, *L.*	Pinnai	Ponna.
Calotropis— gigantea, *Br.*	Erukkam	Jilledu.
Canavalia— ensiformis, *DC.*	Thamattan	Thamma Chamma.

	Tamil.	Telugu.
Canna—		
indica, *L.*	Kalvāzhai	Mettathāmara
Canthium—		
parviflorum, *Lakm.*	Kārai	Balasu.
Capparis—		
sepiaria, *L.*	Sūrai	...
Capsicum—		
annuum, *L.*	Milagāi	Mirapa.
frutescens, *L.*	Do.	Do.
Caralluma—		
adscendens, *Br.*	Kallimolayān	...
Cardiospermum—		
canescens, *Wall.*	Mudakithān	Budda Kākara.
Halicacabum, *L.*	Mudakithān	Do.
Carica—		
Papaya, *L.*	Parangi or Pappāli.	Bobbasi.
Carissa—		
Carandas, *L.*	Perungkalā	Pedda kalavi.
spinarum, *A.DC.*	Kalā	Kalavi.
Cassia—		
auriculata, *L.*	Āvārai	Tangēdu.
Fistula, *L.*	Sarakkonnai	Rēla.
obovata, *Collad.*	Nilāvārai	Nēlatangēdu.
siamea, *Lam.*	Ponnāvārai or Karungkonnai.	Seematangēdu.
Cassytha—		
filiformis, *L.*	Koththān	...
Cedrela—		
Toona, *Roxb.*	Sevvagil	...
Celosia—		
argentea, *L.*	Pannai	Gulugkūra.
Centella—		
asiatica, Urban	Vallārai	...
Cephalandra—		
indica, *Naud.*	Kōvai	Dhonda.
Cerbera—		
Odollam, *Gaertn.*	Udalai	...
Chickrassia—		
tabularis, *Juss.*	Agil	Kondavēpa.
Chloroxylon—		
Swietenia, *DC.*	Karumporasu	Billu.

	Tamil.	Telugu.
Cicer—		
arietinum, *L.* (Bengal gram).	Kadalai ...	... Sanagalu.
Cipadessa—		
fruticosa, *Bl.*	Sevvattai	... Turuka vēpa.
Cissus—		
quadrangularis, *L.*	Perandai	... Nallēru.
Citrullus—		
Colocynthis, *Schrad.*	Pēkkummatti ...	...
Citrus—		
Aurantium, *L.*	Kichili ...	... Naringa or Na-
Cleome—		
viscosa, *L.*	Näikkadugu	... Kukka vāminta.
Clerodendron—		
phlomoides, *L.f.*	Thalanji ...	...
Clitoria—		
Ternatea, *L.*	Kākkattānkodi.	Dintana or Gila karnika.
Cochlospermum—		
Gossypium, *DC.*	Kāttilavan	... Adavi būraga.
Cocos—		
nucifera, *L.*	Thēngu ..	... Kobbirichettu.
procumbens, *L.*	Seruppadai ...	...
Colocasia—		
Antiquorum, *Schott*	Sēppan kizhangu.	Chāma.
Commelina—		
bengalensis, *L.*	Kānavāzhai ...	...
Cordia—		
Myxa, *L.*	Naruvalli ...	...
Cratæva—		
religiosa, *Forst.*	Māvalingan	... Ulimidi.
Crinum—		
asiaticum, *L.*	Vizhamūngal ...	..
Crotalaria—		
juncea, *L.*	Sanal ...	... Janumu.
verrucosa, *L.*	Gilugiluppai ...	...
Cucumis—		
pubescens, *Thw.*	Thummatti or Sukkankāi.	Usthi.
trigonus, *Roxb.*	Thummatti or Sukkankāi.	Do.

	Tamil.	Telugu.
Cucurbita— moschata, *Duch.*	Pūshini	Gummadi.
Curculigo— orchioides, *Gærtn.*	Nilappanai ...	Nēlathāṭi.
Curcuma — longa, *L.*	Manjal	Pasupu.
Cyanotis— axillaris, *R. & S.*	Vazhukkaipillu.	Amirthakāda.
cucullata, *Kunth.* ...	Do.	...
Cynodon— dactylon, *Pers.* ...	Arugampillu ...	Gerike.
Cyperus	Kōraī	Tunga.
Cyperus— arenarius, *Retz.*, rotundus, *L.*	Kōraī	Tunga gaddi.

D

Dæmia— extensa, *Br.*	Vēlipparuthi ...	Juttupāku.
Datura	Umathan ...	Ummeta.
Dichrostachys— cinerea, *W. & A.* ...	Vattathāri ...	Veluturu.
Digera— arvensis, *Forsk.* ...	Thoyyakkīrai ...	...
Dodonæa— viscosa, *L.*	Valāri or Virāli.	Bandaru.
Dolichos— Lablab, *L.*, 11	Avarai or Mochai.	Anapa or Chikkudu.
Dregea—	Kurinja	...

E

Eclipta— alba, *Hassk.*	Karishirānganni.	...
Elettaria— Cardamomum, *Maton* ...	Ēlam	Ēlakkulu.
Eleusine— ægyptiaca, *Desf.*	Mathangāpillu ...	...
Entada— scandens, *Benth.*	Samudrapuliyan.	...
Eriodendron— anfractuosum, *DC.*	Ilavan	Buraga.
Eugenia— Jambolana, *Lam.*	Nāval	Nēredu.

	Tamil.	Telugu.
Euphorbia—		
antiquorum, *L.*	Chadurakalli	Bontakalli.
hirta, *L.*	Ammāmpacharisi.	...
rosea, *Retz.*	Chinna ammāmpacharisi.	...
Tirucalli, *L.*	Tirugukalli	...
Evolvulus—		
alsinoides, *L.*	Vishnukrānthi	Vishnukrāntham.

F

	Tamil.	Telugu.
Feronia—		
Elephantum, *Corr.*	Vilā	Velaga.
Ficus—		
asperrima, *Roxb.*	Pēchchi or Pēthi.	Karakabodda.
bengalensis, *L.* (Banyan)	Alam	Marri.
glomerata, *Roxb.*	Aththi	Bodda.
hispida, *L.*	Pēchchi or Pēthi.	Kukkabodda.
religiosa, *L.* (Peepal)	Arasu	Rāvi.
Tsiela, *Roxb.*	Ichchi	Juvvi.

G

	Tamil.	Telugu.
Gloriosa—		
superba, *L.*	Kalappaikizhangu.	...
Gossypium—		
herbaceum, *L.*	Paruthi	Pathi.
Guazuma—		
tomentosa, *Kunth.*	Thēnpuchikai	...
Gynandropsis—		
pentaphylla, *DC.*	Vēlai	Vaminta.
Gyrocarpus—		
Jacquini, *Roxb.*	Tanuku	Poliki or Tanuku.

H

	Tamil.	Telugu.
Hardwickia—		
binata, *Roxb.*	Ācha	Yēpi.
Helictres—		
Isora, *L.*	Valambiri	...
Heliotropium—		
indicum, *L.*	Tēlkodukkuchedi.	...

	Tamil.	Telugu.
Hibiscus—		
cannabinus, *L.*	Pulichai or Kāchurukai.	Gogu.
esculentus, *L.* (okra)	Bendai	Benda.
micranthus, *L.*	Kuruvippūndu.	...
Rosa-sinensis, *L.*	Sappāthi ...	Dāsani or Mandara.
vitifolius, *L.*	Manituti ...	Karupatti.
Holoptelea—		
integrifolia, *Planch*	Aya	...
Hygrophila—		
spinosa, *T. Anders*	Nīrmulli ...	...

I

Indigofera—		
aspalathoides, *Vahl.*	Sivanarvēmbu ...	...
enneaphylla. *L.*	Cheruppu nerinji.	...
Ionidium—		
suffruticosum, *Ging* ...	Ōrilaitāmarai ...	...
Ipomœa—		
Batatas, *Lamk.* (Sweet Potato).	Sakkarai Valli ...	..
biloba, *Forsk.*	Musalkādukirai.	...

J

Jasminum	Malligai	Malle.
Jatropha—		
Curcas, *L.*	Kāttāmanaku ...	...
Justicia—		
tranquebariensis, *L.f.* ...	Sivānārvēmbu ...	...

Lepidagathis—		
cristata, *Willd.*	1.	...
Leptadenia—		
reticulata, *W. & A.*	Pālaikodi ...	...
Leucas—		
aspera, *Spreng*	Thumbai ...	...
linifolia, *Spreng*	Do. ...	...
Lippia—		
nodiflora, *Rich.*	Poduthulai ...	...
Lycopersicum—		
esculentum, *Miller* (Tomato).	Simaithakkāli ...	...

M

	Tamil.	Telugu.
Mangifera—		
indica, *L.* (Mango)	Mā	Māmidi.
Melochia—		
corchorifolia, *L.*	Punnākku pūndu.	Chittintha kūra.
Michelia	Shenbagam ...	Sampangi.
Millingtonia—		
hortensis, *L.f.*	Mara malli ...	Mānumalli.
Mimusops—		
Elengi, *L.*	Maghizham ...	Pogada.
hexandra, *Roxb.*	Pālai	Pāla.
Mirabilis	Andi malligai ...	...
Momordica—		
Charantia, *L.*	Pāghal	Kākara.
Morinda—		
tinctoria, *Roxb.*	Nunā	Maddi.
Murraya—		
Kœnigii, *Spr.*	Karavēppilai ...	Karēpaku.
Musa—		
paradisiaca, *L.*	Vāzhai	Arati or Arti.
Myristica—		
fragrans, *Houtt.*	Jāthikai ...	Jājikāya.

N

	Tamil.	Telugu.
Naravelia—		
zeylanica, *DC.*	...	Mukkupinata-tiga.
Nelumbium—		
speciosum, *Willd.*	Thāmarai ...	Dāmara.
Nerium—		
odorum, *Soland*	Arali	Gannēru.
Nicotiana—		
Tabacum, *L.*	Pugailai ...	Pogāku.
Nymphæa—		
pubescens, *Willd.*	Alli or Āmbal ...	Kaluva.

O

	Tamil.	Telugu.
Ocimum—		
Basilicum, *L.*	Tirunītrupachai.	...
canum, *Sims.*	Nāithulasi ...	Kukkathulasi.
sanctum, *L.*	Thulasi	Thulasi.
Odina—		
Wodier, *Roxb.*	Udayan	Oddhi or Gum pena.

	Tamil.	Telugu.
Oldenlandia—		
umbellata, *L.*	Chāyavēr ...	...
P		
Pandanus	Thāzhai ...	Mogili.
Panicum—		
frumentaceum, *Roxb.*	Kudirai vāli ...	...
miliaceum, *L.*	Panivaragu ...	...
miliare, *Lamk.*	Sāmai	...
repens, *L.*	Injivērpul or Thandānkattai-pul.	...
Pavonia—		
zeylanica, *Cav.*	Sithāmutti ...	...
Pennisetum—		
typhoideum, *Rich.*	Cumbu	...
Phaseolous—		
Mungo, *L.*	Payaru	...
trilobus, *Ait.*	Naripayaru ...	...
Phœnix—		
sylvestris, *Roxb.*	Īchan	...
Phyllanthus—		
Emblica, *L.*	Nelli	Usiri.
maderaspatensis, *L.*	Mela nelli ...	Nēla usiri.
reticulatus, *Poir*	Pūla	Nallapurugudu.
Physalis—		
minima, *L.*	Siru thakkāli ...	Budama Kayu.
Piper	Milagu	Miriyalam.
Pistia—		
Stratiotes, *L.*	Ākāsathāmarai ...	...
Pithecolobium—		
dulce, *Benth.*	Korukāpili ...	Seemachintha.
Plumbago—		
zeylanica, *L.*	Chitramūlam ...	Chitramūlam
Polianthes—		
tuberosa, *L.*	Nilasampangi ...	...
Polyalthia—		
longifolia, *Benth. & Hook. f.*	Asōgu or Netlingi.	Asokamu.
Polygonum—		
glabrum, *Willd.*	Āttalari ...	...
Pongamia—		
glabra, *Vent.*	Pungan	Kānuga.
Psidium—		
Guyava, *L.*	Koyyā	Jāma.

	Tamil.	Telugu.
Punica—		
Granatum, *L*, (Pomegranate).	Mādalai	Dalimba.
Q		
Quisqualis—		
indica, *L*.	Rangoon malli.	...
R		
Randia—		
dumetorum, *Lamk*.	Markālam ...	Manga.
Raphanus—		
sativus, *L*, (Radish)	Mullangi ...	Mullangi.
Ricinus—		
communis, *L*. (Castor) ...	Āmanakku ...	Āmidapu chettu.
Ruellia—		
prostrata, *Lamk*.	Patāskai chedi ...	...
Santalum	Sandanam ...	Srigandapu manu.
Sapindus—		
emarginata, *Vahl*.	Pūngankottai or Ponnangkottai.	Kūgati.
Sarcostemma—		
brevistigma, *W. & A.*	Kodikkalli ...	...
Sesbania—		
ægyptiaca, *Pers*.	Karum sambai or Sithagatti.	Nalla sominta.
grandiflora, *Pers*.	Āthi	Avisi.
Setaria—		
italica, *Beauv*.	Tenai	Korra.
Solanum—		
Melongena, *L*. (Brinjal) ...	Kaththiri ...	Venkāya or Vanga.
nigrum, *L*.	Milaguthakkāli or Manatha-kāli.	...
torvum, *Sw*.	Sundai	...
tuberosum, *L*. (Potato) ...	Urulaikizhangu.	Urlagadda.
xanthocarpum, *Schrad & Wendell*.	Mullikāi or Kandang kathiri.	...
Spermacoce—		
hispida, *L*.	Thātharā ...	...

	Tamil.	Telugu.
Streblus—		
asper, *Lour.*	Pirāyan	Baranika.
Synantherias—		
sylvatica, *Schott.*	Kāttukaranai ...	...

T

Tamarindus—		
indica, *L.* (Tamarind)	Puliyan	Chintha.
Tephrosia—		
purpurea, *Pers.* ...	Kolinji	Vempali.
villosa, *Pers.*	Kolinji	...
Terminalia—		
Arjuna, *W. & A.* ...	Maruthu ...	Tella maddi.
Catappa, *L.* ...	Nattu Vadumai.	Badāmi.
Chebula, *Retz.* ...	Kadukkāi ...	Karaka.
Thespesia—		
populnea, *Corr.* ...	Pūvarasu ..	Gangaravi or Gangarēni.
Toddalia—		
aculeata, *Pers.* ...	Milagāranai ...	Konda kasinda.
Trapa—		
bispinosa, *Roxb.* ...	Singārakottai ...	...
Trianthema—		
decandra, *L.*	Sāranai or Sārvalai.	Galijēru.
Portulacastrum, *L.*	Vellai Sāranai or Sārvalai.	Tella Galjeru.
Tribulus—		
terrestris, *L.*	Nerinji	Pallēru.
Trichodesma—		
indicum, *Br.*	Kazhuthai thumbai.	...
Trichosanthes—		
anguina, *L.*	Pudal	Potla.
Typhonium—		
trilobatum, *Schott.*	Kārungkaranai.	

U

Urginea—		
indica, *Kunth.*	Narivengāyam ...	

	Tamil.	Telugu.
V		
Vallisneria—spiralis, *L.*	Vēlampāsi ...	...
Ventilago—madraspatana, *Gærtn.* ...	Vembadam ...	...
Vernonia—cinerea, *Less.*	Mūkuthipūndu.	...
Vigna—Catiang, *Endl.*	Kārāmani ...	Alasanda or Bobbarakāya.
Vinca—pusilla, *Murr.*	Milagai poondu.	..
rosea, *L.*	Pillayārpoo or Thulukka-malli.	Billaganneru.
Vitis—vinifera, *L.* (Grape)	Drakshi ...	Draksha.
W		
Withania	Amūkran kish-angu.	...
Wrightia—tinctoria, *Br.*	Veppālai ...	Tedlapāla or Ankudu.
X		
Xanthium—Strumarium, *L.*	Marūl ūmathan.	...
Z		
Zea—Mays, *L.* (Maize)	Makkācholam ...	Mokka Jonna.
Zingiber—officinale, *Rosc*	Inji	Allam.
Zizyphus—Jujuba, *Lamk.*	Ilandai	Rēgu.
Œnoplia, *Mill.*	Sūrai	Banka.
xylopyrus, *Willd.*	Kottai	Gotti

GLOSSARY.

A

Accessory fruits, fruits reinforced by stem, or other structures as in Jack fruit, apple, etc., 280.

Achene, one-seeded, dry, indehiscent fruit, 283, 375.

Achlamydeæ, flowers without a perianth, 520

Acropetal, from top downwards, produced in a succession towards the apex as applied to development of organs, 35.

Acuminate, applied to the apex of a leaf when it is prolonged into a fine point, 127.

Acute, applied to the leaf apex when it is pointed without being drawn out, 127.

Adnate, attached to the whole length; also applied to anther-lobes attached by their entire length to the filament, 423.

Adventitious, arising at unusual places: as buds at other places than nodes or roots at places other than roots, 26, 36, 312.

Æcidia, cup shaped bodies occurring in fungi and producing spores on the hymenium inside, 474.

Æcidiospores, spores formed in Æcidia, 474.

Ærenchyma, tissue of thin-walled cells with large air spaces found in the stems of marsh plants serving for aeration or floating, 429.

Ærial roots, roots that develop in the air, 66.

Æstivation, applied to the folding in of the sepals and petals in the bud, 249.

Aggregate, forming a dense cluster: applied to fruits formed of a flower and with free carpels, 286.

Ala (pl. alæ), the lateral petal of a papilionaceous corolla or the wing-petal, 238, 248.

Aleurone grains, proteid grains present in seeds, especially in oily seeds, 31.

Aleurone layer, the special outer layer of regular cells with proteid granules in the grains of grasses, 31.

Algæ, lowly organised plants either unicellular or multicellular without tissue differentiation, but containing chloroplasts, 462.

Allelomorphs, unit characters existing in antagonistic pairs, 492.

Alternate, at intervals one after the other: said of leaves when they arise singly at the nodes, 118.

Amplexicaul, applied to leaves when they embrace the stem, stem clasping, 391.

Anabolism, the constructive chemical changes of the protoplasm leading to the building up of more complex from simpler substances 192.

Andrœcium, stamens of a flower collectively.

Androphore, stalk bearing the stamens.

Angiosperm, plants whose seeds are enclosed in an ovary, 315.

Annular vessel, vessel having thickenings disposed in the form of transverse rings, 47, 143.

Annulus, the region or ring of thickened cells in the sporangia of ferns, 442.

Anther, the portion of the stamen which contains the pollen-grains, 7.

Antheridium, the male organ in cryptogams which produces sperm-cells, 444, 454.

Antherozoid, motile sperm-cell provided with cilia, and formed in antheridia, 444.

Antipodal cells, the three cells at the base of the embryo sac formed by the division of the primary nucleus, 260.

Apocarpous, applied to fruits when the carpels are quite free from each other, 253.

Appressed, close and flat against; applied to hairs, 386.

Archegonium, the female organ on the prothallus of ferns or found in other cryptogams producing the egg-cell, 444, 454.

Aril, an appendage on the seed arising from the stalk or from the micropyle, 291.

Auricled, said of leaves with basal lobes shaped like an ear, 125.

Awn, a bristle-like appendage usually found on the glumes of grasses, 421.

Axil, the angle formed by a leaf with the stem on the upper side, 5.

Axile placentation, applied to an ovary when the ovules are attached to the central axis, 252.

Axillary bud, a bud arising in the axil of a leaf, 73.

Bacterial nodules, swellings formed in the roots of leguminous plants by bacteria which are able to fix the free nitrogen of the air, 68.

Bacterium (pl. Bacteria), lowest very minute plants devoid of chlorophyll, 1, 68, 216.

Basidia, large cells found on the surface of the gills of a mushroom, or on the corresponding surface of any of the related fungi at whose ends the spores are produced, 477.

Basidiospores, spores formed on or borne by basidia, 474, 476.

Basifixed (or innate), applied to anthers when attached at the base, 251.

Basipetal, growth in the direction of the base, 231.

Berry, a fruit with a pericarp fleshy throughout, 281.

Bifarious, leaves two-ranked or arranged in two vertical rows. 421.

Bilabiate, having two lips, 391.

Bipinnate, twice pinnate, having both primary and secondary divisions of a pinnate compound leaf, 127.

Bisexual, said of a flower with both stamens and pistil, 235.

Blade, the expanded portion of a leaf, 114.

Bordered pit, a pit in which the margin projects over the thin closing membrane, 143.

Botryose (or **racemose**), applied to an inflorescence in which the flowers develop in regular acropetal succession, so that the older flowers are at the base and the younger at the top, 229.

Bract, reduced leaf subtending a flower or an inflorescence, 128, 226.

Bracteate, provided with bracts.

Bracteole, a small bract placed below the flower on the pedicel, but not subtending it, 237.

Brand spore, a spore with a thick membrane, 475.

Bryophyta, group of plants including mosses and liverworts, 439.

Bud, an undeveloped condensed shoot, all the parts being very young and small and the more delicate younger parts being protected by the older parts, 5, 12, 74.

Bulb, a modified underground shoot having a short flat stem with numerous roots below and scaly leaves and buds above, 85.

C

Caducous, applied to sepals or petals falling off very early, 246.

Callus, mass of cells formed on cut or exposed surfaces by the active division of cambium and parenchyma, 112.

Calyptra, the membranous covering over the capsule of a moss, formed from the apex of the archegonium, 455.

Calyx, the outermost whorl of a typical flower; the sepals collectively, 6, 246.

Cambium, the layer of living cells lying close to the wood in stems and roots which leads to the secondary thickening of stems and roots, 51, 90, 91, 159.

Campanulate, bell-shaped.

Capitulum, flower-head; an inflorescence in which the flowers are sessile and crowded at the end of the stalk of the inflorescence, 228.

Capsule, a dry fruit formed of more than one carpel which opens to let the seeds escape, 285.

Carbohydrate, a substance formed out of carbon, hydrogen, and oxygen, the two latter being in the same proportion as in water, 184.

Carpel, a simple pistil, or part of a compound pistil, 253.

Caruncle, a massy outgrowth on a seed near the hilum, as in castor seed, 20, 291.

Caryopsis, a seed-like fruit in which the pericarp and testa are fused together; applied to the grains of grasses, 283.

Cell, the unit of plant structure or a bit of protoplasm enclosed by a cellulose membrane, the cell-wall, 26, 137.

Cell-sap, the liquid content of a cell having certain salts, sugars, etc in solution, 29, 146.

Cellulose, the substance which goes to form the cell-wall when young and having the same composition as starch, 32, 144.

Cell-wall, the wall of a cell originally composed of cellulose but altered later on by deposition of other substances, 28, 142.

Centrifugal, from the centre to the periphery ; said of an inflorescence when the order of opening is from the top to the base or from the centre to the periphery, 52, 231.

Centripetal, applied to an inflorescence whereof the flowers are developing from without inwards, as opposed to centrifugal, 49, 230.

Chlorenchyma, the assimilating tissue or the interior parenchyma of a leaf, 133.

Chlorophyll, the green colouring matter of plants contained in chloroplasts, 141, 186.

Chloroplasts, the masses of protoplasm which are of a green colour and found imbedded within the protoplasm of cells of parts exposed to light, 141.

Chromatin, the portion of the nucleus which readily takes the artificial staining, 140.

Chromatophore, a collective term for all plastids, 141.

Chromoplast, a plastid containing other colouring matter than chlorophyll, 142.

Chromosomes, staining bodies of definite number into which the body of the nucleus divides in nuclear division, 147, 148.

Cilliate, fringed with hairs or cilia.

Circinnate, coiled downwards from the tip, applied to the folding of the leaves when young, 440.

Circulation, the peculiar streaming movement of protoplasm seen in living cells, 139, 225.

Cladophylla or **Cladode**, flattened stems or branches doing the functions of leaves and sometimes appearing like them, 132.

Clavate, club-shaped.

Claw, the narrowed base of certain petals ; the stalk of a petal.

Cleft, divided about half way in the leaf-blade, 126.

Cleistogamous, said of unopened flowers which are self-fertilised 264.

Coccus, the dry portion or carpel of a schizocarp or splitting fruit, 283.

Collenchyma, a kind of strengthening tissue beneath the epidermis formed of living cells thickened at the corners, 96, 111, 157.

Comose, having a tuft of hairs, 291.

Compound, said of a leaf whose blade is cut into separate pieces (leaflets) so that one piece (a leaflet) could be detached without injuring others, 6. 126.

Conduplicate, folded together applied to leaf-blades, 116.

Cones, the flower clusters of cycads and conifers, 509.

Conjugation, fusion of two sexual elements or gametes which are similar ; the union of like gametes, 465.

Connective, the portion of the stamen which connects the filament with the anther and its lobes, 251, 256.

Contorted (twisted), said of a corolla in which each petal regularly covers, and is covered by another petal, 249.

Convolute, said of leaves when rolled up along the length from one margin to the other, one being over the other, 116.

Cordate (or heartshaped), applied to a leaf-blade, 125.

Cork cambium, a layer of living cells which by active division forms the cork-tissue, 156.

Cork-tissue, a kind of protective tissue formed on old stems and roots and also on cut or exposed surfaces consisting of dead cells whose walls are impervious to water and gases, 100.

Corm, a modified underground fleshy stem or bases of stems having buds and with or without scales, 85, 311.

Corolla, the petals of a flower collectively, 6, 247.

Corona, an out-growth from the corolla or from the stamens, 248.

Corpuscle, the small blackish or brownish mass connecting the arms of the pollen-masses in Asclepiads, 381.

Cortex, the portion of stem or root lying between the epidermis and the stele, 46, 88, 96.

Corymb, a flat-topped inflorescence of the racemose type (also applied to cymose type) having the lower older pedicels longer than the upper younger ones, 227.

Cotyledon, the seed leaf or leaves of the embryo plant formed inside the seed, 11, 127.

Crenate, applied to the margin of leaves when it has rounded teeth, 125.

Cross-pollination, transference of pollen to the stigma of a flower from a flower of a different individual, 262.

Cryptogams, flowerless plants; literally plants whose sexual parts are hidden, 1, 438.

Cuneate or **Cuneiform**, wedge-shaped, 440.

Cupule, cup-like structures on the thallus of some liverworts containing gemmæ or vegetative buds, 458.

Cuspidate, applied to the apex of a leaf which possesses a small triangular piece, 127.

Cuticle, the outer lining on the epidermis of leaves and stems and formed of the substance cutin which is impervious to water, 30, 138.

Cyclic, arranged in whorls, 521.

Cyme, a flat-topped or convex flower cluster in which the central flower is the first to open, 231.

Cymose, an inflorescence in which the primary axis ends in a flower and gives rise to branches which repeat the same process; also termed centrifugal, 78, 230.

Cytoplasm, all the substance within the living cell, except the nucleus, 138, 139.

D

Deciduous, falling off at the end of the growing season, applied to leaves and petals, 246.

Decompound, more than once compound, 127.

Decurrent, applied to a sessile leaf blade when it extends down the stem in the form of a wing.

Decussate, arrangement of opposite leaves placed at right angles to each other and forming four rows on the stem, 120.

Definite, applied to cymose type of inflorescence, 231.

Dehiscence, the act of opening of anthers or fruits, 251, 285.

Dentate, applied to the margin of leaves with straight teeth, 125.

Diadelphous, said of stamens united by their filaments into two bundles, 239.

Diastase, the enzyme or ferment which converts starch into sugar, 30, 195.

Dichasium (dichotomous cyme), a cymose inflorescence with branches arising in pairs, 231.

Dicotyledonous, having two cotyledons or seed leaves, 315.

Didynamous, said of stamens, when there are two pairs of them, one pair longer than the other, 250.

Digestion, transformation of insoluble substances in a cell into forms in which they may be dissolved, 195.

Digitate (or **palmate**), applied to a lobed or compound leaf in which all the lobes or leaflets are attached at the end of the petiole, 9, 126.

Dimorphic (or **dimorphous**) occurring in two forms, 239.

Diœcious, having the sexes separated in two distinct individuals, 243.

Disk, the central part of the head of a compositæ as opposed to the margin; also a flat or annular structure found in a flower around the ovary.

Distichous, in two vertical rows.

Dominant, in hybrids the character which is prevalent as opposed to a character which is hidden (recessive), 492.

Dorsal suture, the midrib of a carpel, or its back side, 254.

Dorsifixed (or **adnate**), fixed on the back; said of anthers, 251.

Drupe, a fleshy one-seeded fruit having a stony endocarp; a stone fruit, 281.

E

Egg-cell, the female cell in the embryo-sac which develops into an embryo after fertilization, 260.

Elater, a spirally marked thread borne among the spores of some liverworts and slime moulds, 459.

Emarginate, having a decided terminal notch, 127.

Embryo, the young plant contained in the seed, 11, 292.

Embryo-sac, the cell in the ovule in which the embryo is formed, 259.

Endocarp, the innermost layer of the pericarp, 281.

Endodermis, the innermost layer of the cortex forming a sheath round the stele, 49, 96.

Endogenous, arising from deep-seated tissues, 219.

Endosmosis, passing of a liquid through a membrane into a more concentrated fluid, 169.

Endosperm, the reserve food stored outside the embryo and within the embryo-sac in seeds, 20, 140, 290.

Energy, the capacity for doing work, 187.

Energy, kinetic, the energy of actual motion, 207.

Energy, potential, energy not manifested in action, but stored, 207.

Entire, said of a leaf margin which is neither indented nor toothed, 125.

Enzyme, a substance formed in a living cell which causes chemical changes in other substances, without itself undergoing any change, 195.

Epicalyx, bracts placed outside the calyx in certain flowers, as in Malvaceæ; also called involucre or involucral bracts, 239.

Epicarp, the outermost layer of the pericarp in a fruit, 281.

Epidermis, the outer protective layer of cells of leaves and young stems, 88, 96, 153.

Epigeal, said of cotyledons coming out of the ground in germination 24.

Epigynous, applied to a flower in which the other parts rise from above the ovary, as the result of the fusion of the hollow receptacle with the pericarp of the ovary, 251, 255.

Epipetalous, applied to stamens arising from the corolla tube, 241, 250.

Epiphytes, plants growing on other plants for the sake of attachment but not parasitic, 66, 435.

Exodermis, the thickened layer or layers of cells beneath the piliferous layer of roots, 57.

Exogenous, arising from external tissues and having cambium, 218.

Exosmosis, flow of a fluid outwards through a membrane into a less dense fluid, 169.

Exserted, said of stamens when they protrude beyond the tube of the corolla.

Exstipulate, without stipules.

Extrorse, said of anthers when they open outwards, i.e., towards the petals and away from the pistil, 252.

F

Falcate, sickle or scythe-shaped.

Family, a group of related genera, 315.

Fascicle, a condensed cluster of flowers, leaves, stems or roots,

Fertilization, the fusion of the germ-cell of the pollen-grain with the egg-cell in the ovule which leads to the formation of an embryo, 7 256.

Fibres (or **sclerenchyma**), long, narrow, thick-walled cells tapering at both ends found in the mechanical tissue of plants, and without any contents, 49.

Filament, the stalk of the stamen, 7.

Filiform, slender or thread-like.

Follicle, the free dry carpel of an apocarpous fruit opening at the front or ventral suture only, 284.
Free-central placentation, attachment of the ovules to anaxis in the fruit which is not connected with the wall of the ovary but arises from the bottom of it ; also called basal placentation, 253.
Frond, the leaf of fern, 440.
Fruit, ripened ovary with its contents, 279.
Fugacious, falling off soon,
Fungus, a plant of low organization and devoid of chlorophyll, 469.
Funicle, the stalk of the ovule or the seed, 397.

G

Gametes, specialized bits of protoplasm whose fusion is necessary for the formation of seed, 308.
Gametophyte, the generation of a plant which bears the sexual organs and gives rise to the sporophyte, 443, 445, 458.
Gamopetalous (or **Monopetalous**), applied to corollas having petals united together, 239.
Gamosepalous (or **Monosepalous**), applied to a calyx with united sepals, 239.
Gemma, bud-like body found in cup like structures on the flat bodies of some liverworts and capable of developing into an individual, 458.
Genus, the smallest natural group containing distinct species, 315.
Geotropism, movement in parts of plants in response to the stimulus of gravity, 222.
Geotropism, negative, turning away from the earth, as stems, 222.
Geotropism, positive, going towards the earth, as roots, 222.
Germination, the development and emergence of the embryo from the seed, 19.
Gill, one of the vertical flaps on the under side of the cap of a mushroom, on whose surface spores are borne, 477.
Glabrous, smooth without hairs,
Gland, an organ of secretion or a small prominence having a secreting function, 236
Glaucous, covered with a bloom,
Glume, the scale-like bract in the inflorescence of grasses and sedges, 419, 420.
Grafting, attachment of the parts of two plants in such a way that they will unite and grow together.
Growing point, the growing tip of a stem or root consisting of embryonic cells from which the different tissues arise, 41.
Guard cells, the cells which go to form the stomata and regulate their opening, 134.
Gymnosperm, a plant in which the ovules are naked and not enclosed, 508.
Gynandrous, applied to stamens adhering to the pistil, 249.
Gynæceum, pistil or pistils of a flower taken collectively, 252.

Gynobasic, having an enlargement or prolongation of the receptacle bearing the gynæceum applied to the style, 400.

Gynophore, stalk of the pistil more or less elongated, 328.

Habitat, locality in which a plant grows.

Halophytes, plants thriving in saline places, 433.

Haplochlamydeous, having a single perianth.

Hastate, applied to the leaf-blade when its basal lobes are turned outwards, 125.

Haustorium (pl. haustoria), the sucking organ of a parasitic plant which penetrates the host to obtain food, 69, 210.

Head (or **capitulum**), an inflorescence in which the flowers are sessile, and crowded at the top of the peduncle, 228.

Helicoid cyme, an inflorescence of the sympodial type in which the lateral branches are developed on one side only, 231, 388.

Hermaphrodite, applied to flowers having both the stamens and pistil in the same flower, 235.

Hesperidium, a superior syncarpous berry, like the orange, formed of many carpels and covered by a tough rind, 282.

Heterocyclic, floral whorls not uniform.

Heterogamous, having two kinds of flowers in the head, as in Compositæ, 374.

Heterosporous, having two kinds of spores,

Heterozygote, a zygote resulting from the fusion of the gametes of a pair of allelomorphs, 494.

Hilum, the scar left on the seed by the funicle or placenta to which it was attached (also applied to the central point or nucleus of a starch grain round which the layers are seen).

Hirsute, beset with stiff hairs.

Homochlamydeous, having perianth leaves all alike.

Homogamous, having flowers all of one kind, 375.

Homosporous, having one kind of spore only, 449.

Host, a plant which nourishes a parasite, 210.

Hyaline, colourless or translucent.

Hyaloplasm, the clear non-granular portion of the protoplasm, 139.

Hybrid, a plant produced by the crossing of two species or varieties, 491.

Hydrophytes, plants adapted to an aquatic mode of life, 426, 427.

Hydrotropism, curvature induced by the stimulus of moisture, 223.

Hymenium, the layer or layers bearing the spores in the sporophore of a fungus, 477.

Hypha, one of the thread-like elements found in the body of a fungus, 470.

Hypocotyl, the portion of the seeding which is below the cotyledons and above the root, 15.

Hypocrateriform, said of the corolla with a long tube and flat spreading limbs; salver-shaped, 247, 329.

Hypogeal, said of seedlings when the cotyledons lie below ground, 25.

Hypogynous, applied to flowers, when the stamens and the perianth are at the base of the ovary, 250, 255.

Imbibition, passage of water through cell-wall and protoplasm by making them more porous, 168.

Imbricate, the overlapping of petals or sepals in such a way that one or more parts have both their margins completely inside, 249.

Indefinite, not definite; when applied to an inflorescence it means, the older flowers are at the bottom or outside and the youngest at the top or centre, 230.

Indehiscent, said of fruits not opening or splitting to shed their seed, 283.

Indusium, covering of sori in ferns.

Inferior, said of an ovary surmounted by the other parts of the flower.

Inflorescence, collection of flowers on an axis, 226.

Innate, applied to an anther when joined by its base to the apex of a filament, 251.

Integument, the covering of the ovule, 259.

Internode, the portion of the stem between two nodes or joints, 5.

Introrse, applied to anthers which open inwards towards the pistil as opposed to extrorse, 252.

Involucre, a series of bracts surrounding several flowers or their supports, as in the heads of compositæ or in the umbels of umbelliferæ.

Involute, leaf edges rolling inwards from both the margins as in the Lotus leaf, 116.

Karyokinesis, nuclear division; same as mitosis, 147.

Katabolism, chemical changes occurring in the protoplasm and resulting in the decomposition of substances, 192.

Keel, the boat-shaped anterior petals of a papilionaceous flower, 238. 248.

Kidney-shaped, reniform; applied to organs which are crescent-shaped with rounded ends, 125.

Labiate, lipped; said of a gamopetalous corolla having an upper and lower lip, as in Leucas, 247.

Lamella, a thin plate found in a thickened cell-wall, 142.

Lamina, the blade of a leaf, 114.

Lanceolate, shaped like a lance; applied to a leaf having a somewhat broad base and tapering towards the apex, 124

Latex, the milky secretion of such plants as Euphorbia, Ficus, 162.

Latex tubes, tubes containing a milky juice, as in Euphorbia, 162.

Leaflet, a separate segment of a compound leaf, 6.

Legume, a monocarpellary fruit opening by both the margins, 284.

Lenticel, a spot in the bark intended to facilitate exchange of gases and consisting of loosely arranged cork-cells, 43, 157.

Lianes, applied to large woody climbers, 80.

Lichen, a cryptogam formed of a fungus and an alga, 213.

Lignification, the thickening of cell walls by means of lignin, 144.

Ligulate, applied to the strap-shaped corolla of the ray florets in the head of a compositæ, 248, 374.

Ligule, a structure found at the junctions of the blade and the sheath in the leaves of grasses, 420.

Limb, the border or the expanded part of a monopetalous corolla, the blade of a leaf or petal.

Linear, applied to a leaf, petal or sepal, when it is very long and narrow, 124.

Loculicidal, applied to the dehiscence of a capsule when the opening is by the dorsal or back side so as to expose the cavity, 285.

Lodicule, small scale found in the flowers of grasses just outside the stamens, 420.

Lomentum, a legume constricted between the seeds and separating into one-seeded parts, 284.

Lysigenous, applied to cavity formed by the disorganization of cells, 165.

M

Mechanical tissue, the tissues which contributes to the rigidity and strength of plant organs, 107.

Medulla (or **pith**), the central core within the stele of dicotyledonous stems, 88.

Medullary rays, the rows of parenchyma cells which extend from the pith to the cortex, 88.

Megasporangia, sac producing megaspores, 445.

Megaspore (Macrospore), the larger spore in a pteridophyte, when two kinds are produced, 445.

Mogasporophyll, a leaf bearing megaspores, 510.

Mericarp, one carpel of the fruit of an umbellifer, 371.

Meristem, the active dividing uniform cells in plants located in young parts at the growing points, 41.

Mesocarp, the middle portion of the pericarp in fruits, 281.

Mesophyll, the parenchyma which form the chief part of the interior of a leaf, 134.

Mesophyte, a plant flourishing in habitats having a moderate amount of humidity in air and soil, 437.

Metabolism, chemical changes occurring in an organism, 192.

Micropyle, the hole in the ovule through which the pollen-tube enters in the act of fertilization; also the aperture found in the seed coat, 11, 259.

Microsporangium, a sac producing microspores, 445.

Microspore, the smaller spore in a pteridophyta, when the spores are of two kinds and the pollen grain of a flowering plant, 445.

Microsporophyll, leaves bearing microspores, 510.

Mitotis, Nuclear division or indirect division of cells, 147.

Monadelphous, applied to stamens united together by the filament forming one bundle or a tube, 249.

Moniliform, like a string of beads, 359.

Monocarpellary, formed of one carpel only, 253.

Monochasium, a cyme with one main axis, 234.

Monocotyledon, a plant having only one cotyledon, 315.

Monœcious, having the stamens and pistil on separate flowers but on the same plant, 243.

Monopetalous, same as gamopetalous, 241.

Monopodial, applied to a stem or axis resulting from the activity of a single terminal growing point, 77.

Monosepalous, same as gamosepalous, 238.

Mucronate, having a mucro or a sharp point at the apex of a leaf, 127.

Multiple fruit, a fruit consisting of the pistils of a number of flowers, consolidated into a mass, 289.

Mycelium, the vegetative portion of a fungus consisting of hyphæ 470.

Mycorrhiza, fungus found in association with the roots of certain plants either within or without and for the advantage of both, 213.

N

Nectary, an organ which secretes nectar or honey, 268.

Node, the part of the stem whence leaves arise, 5.

Nucellus, the body of the ovule within the integument containing the embryo-sac or megaspore—the megasporangium, 259.

Nucleolus, a sharply defined small body found inside a nucleus, 140.

Nucleus, the important part of a living cell which is of a denser nature and which initiates the division of a cell, 29. 140.

Nut, a hard indehiscent one-seeded fruit.

Obcordate, inversely heart-shaped, the notch being apical.

Oblanceolate, lanceolate with the broadest part towards the apex.

Oblique, unequal sided,

Oblong, applied to a leaf-blade or a perianth lobe when it is longer than broad with more or less parallel sides, 124.

Obovate, applied to a leaf-blade when it is egg-shaped but with the narrow end towards the base, 125.

Obtuse, said of the apex of a leaf-blade when it is rounded, 127.

Ochrea (Ocrea), tubular stipule, 115.

Opposite, applied to leaves arising in pairs at the same node, 118.

Orbicular (or **rotund)**, said of a leaf having a round outline, 125.

Osmosis, diffusion of fluids through a membrane, 169.

Ovary, the portion of the pistil which contains the ovules, 7

Ovate, shaped like an egg, the broader end being near the base, 125.

Ovule, the part of the ovary which develops into seed after fertiliza tion, 259.

P

Palea, the scale-like part which covers the flowers of grasses and this is two-nerved, 420.

Palisade parenchyma, parenchyma consisting of elongated chlorophyll containing cells found below the upper epidermis of most leaves, 134.

Palmate, same as digitate, 9.

Panicle, an open mixed inflorescence, racemose or cymose or both, 234.

Papilionaceous, having the shape of a butterfly; said of a corolla made up of a standard, two wing-petals and a keel formed of two petals, 248.

Pappus, the hairy or bristle-like outgrowth found on the top of the ovary or seed of certain Compositæ, 375.

Parasite, a plant living on another called its host, 211.

Parenchyma, the cellular ground tissue of plants consisting of thin walled cells, 162.

Parietal placentation, attachment of ovules to outgrowths on the inner wall of the ovary, 253.

Pedicel, the stalk of an individual flower, 237.

Peduncle, the flower stalk of a solitary flower or of an inflorescence.

Peltate, applied to a leaf attached to the stalk on the lower surface instead of at the margin, 323.

Pentamerous, with the parts in fives, 315.

Pepo, the fruit of a gourd; an inferior one-celled fruit with a hard rind and parietal placentation, 282

Perianth, the floral envelopes, calyx and corolla, 245.

Peribelm, the embryonic layers beneath the epidermis at the growing point, which become developed later into cortex, 150.

Pericarp, the wall of the fruit, 279.

Pericycle, the ring of cells of the stele just within the endodermis, 50.

Periderm, the cork tissue, 156.

Perigynous, said of the flower when the perianth and stamens are placed round the ovary, 251.

Perisperm, reserve food formed in the ovule outside the embryo-sac. 290.

Persistent, remaining for a long time as the calyx on some fruits e.g., Brinjal, 246.

Petal, part of a corolla usually brightly coloured, 6.

Petaloid, said of sepals when coloured like petals, 247.

Petiole, the leaf-stalk, 6.

Phelloderm, the innermost layer of the periderm, 156.

Phellogen, the cork cambium, 156.

Phloem, the portion of a vascular bundle consisting of sieve-tubes and parenchyma, 50.

Photosynthesis, formation of starch from water and carbon dioxide within the chloroplastids under the influence of sunlight, 186.

Phyllode, a flattened petiole assuming the form and functions of a leaf, 132.

Phyllotaxis (or **phyllotaxy**), the arrangement of leaves on the stem, 118.

Pileus, a convex expansion terminating the stipe of a mushroom, and bearing the hymenium, 477.

Piliferous layer, the outermost layer of cells in the root which produces the root-hairs, 45.

Pinnate, said of a compound leaf having the leaflets arranged in two opposite rows on a common petiole, 10.

Pinnule, a secondary leaflet, 443.

Pistil, the innermost part of a complete flower consisting of the ovary, style and stigma, 7.

Pistillate, applied to flowers having the pistil alone, without the stamens, 242.

Pistillode, an undeveloped pistil.

Placenta, the outgrowth in the ovary which bears the ovules, 252.

Plasma membrane, the limiting protoplasmic membrane at the exterior of plant cells which are without cell-walls, or the membrane which lies in immediate contact with the cell-wall when it is present, 139.

Plasmolysis, the separation from the cell-wall of the protoplasm as a result of osmotic action, 169.

Plastid, a specialised portion of the protoplasm having a definite work to do, such as the manufacture of starch, chlorophyll or other pigments, 141.

Plerome, the central core of tissue in the growing point beneath the periblem, 150.

Plumose, having feathery outgrowths, 299.

Plumule, the part of the axis of the embryo in the seed above the insertion of the cotyledons, 12.

Pneumatophore (or **pneumathode**); the breathing roots of certain plants such as those of Avicennia, 69.

Pollen, the yellow powdery substance found in the anther lobes, 7.

Pollination, the transference of pollen from the anther to the stigma of the same or another flower, 7.

Pollinium (pl. pollinia), a pollen-mass composed of all the pollen grains, in a pollen-sac, 275.

Polygamous, having unisexual as well as hermaphrodite flowers in the same plant or species, 243.

Polypetalous, having many free petals.

Pome, an inferior fleshy fruit in which the fleshy part consists of the receptacle and adnate calyx, 282.

Posterior, next or towards the main axis, superior or upper side.

Primary axis, the axis in the embryo which develops into the main stem, 11.

Primary medullary rays, the first formed rows of parenchymatous cells which radiate from the pith to the cortex between the vascular bundles, 95, 96.

Primary meristem, the formative tissue of a young organ, 51.

Procambial strands, bands of tissue in the procambium which ultimately become vascular bundles, 94.

Procambium, the ring of small embryonic tissue in the stele from which vascular bundles arise, 94, 152.

Protandrous, applied to a flower in which the stamens shed their pollen before the stigma is receptive, 265.

Proteid, a complex nitrogenous substance consisting of carbon, hydrogen, nitrogen, sulphur and phosphorus, 194.

Prothallus (prothallium), the gametophyte of ferns and other pteridophytes, resulting from the germination of an asexual spore, 443.

Protogynous, applied to a flower in which the stigma is ready to receive the pollen before the anthers are mature, 264.

Protonema, a thread-like vegetative growth produced by the germinating spore of a moss, and on which the conspicuous moss plant is developed as a lateral or terminal shoot, 455.

Protoplasm, the living substance of plants consisting chiefly of proteids, 28, 137.

Pteridophytes, fern plants and their allies, 439.

Pyrene, the small portion of a drupe, 282, 372.

Pyrenoid, colourless bodies found in chloroplasts of algæ, 465.

Pyxis, a capsule which opens transversely by the separation of a lid, 286.

Q

Quincuncial, said of the æstivation of calyx or corolla with five parts, two being in, two out and one in and out, 241, 249, 340.

R

Raceme, an inflorescence having a main axis with stalked flowers on it arranged in acropetal succession, 227.

Racemose, same as botryose, 229.

Rachis (Rhachis), the axis of an inflorescence, compound leaf or frond.

Radicle, the part of the primary axis of the embryo lying below the attachment of the cotyledons, 12, 24.

Ramenta, thin chaffy scales found in the epidermis of ferns, 439.

Raphe, the continuation of the seed stalk along the side of an inverted ovule.

Receptacle, the dilated end of the flower stalk from which all the parts of the flower arise; also called torus, or thalamus, 235; 255.

Recessive, applied to a character in a hybrid when it is hidden but appearing in the offspring of hybrids, 492.

Reniform, same as kidney-shaped, 125.

Respiration, the breaking down of protoplasm and food in it as a result of which energy is set free for the use of the organism, 204.

Response, change produced in a cell or organism as a result of a stimulus.

Reticulated vessels, vessels with thickenings in the form of a network, 47, 143.

Retuse, applied to the apex of a leaf when it is notched, 127.

Revolute, rolled backwards or downwards.

Rhizoid, an elongated cell or a row of cells serving as a root in mosses and liverworts, 444, 453.

Rhizome, a creeping underground stem sending roots down and shoots above, 84.

Rhizomorph, branched strands of mycelial hyphæ, 477.

Rhizophore, a slender but stiff leafless branch in Selaginella, which develops true roots on reaching the soil, 451.

Root-cap, the structure found at the extreme end of young roots forming a protective covering, 35.

Root-hairs, elongated cells of the piliferous layer in the youngest portions of roots, 44.

Root-sheath, special covering of the radicle in monocotyledonous seeds especially in grains, 23.

Root-sucker, a shoot originating from the root, 36.

Rotate, wheel-shaped; applied to a united corolla having a short tube and spreading limbs, 247.

Rotation, a peculiar kind of movement of protoplasm, 138, 225.

Runner (or stolon), a prostrate branch which strikes roots and develops shoots, 80.

S

Sagittate, applied to a leaf blade having two straight lobes at the base and shaped like an arrow, 125.

Samara, an indehiscent winged fruit, 283.

Saprophytes, plants that take nourishment from dead organic matter, 213, 469.

Scalariform vessels, vessels having thickenings in the form of a ladder, 47.

Scale-leaves, small leaves which are found in underground shoots or stems above ground, 19, 127.

Scape, a leafless peduncle arising from a subterranean stem, 323.

Schizocarp, a dry fruit which splits into separate parts or segments, 283.

Schizogenous, cavity formed by the splitting of the cells and the intercellur space enlarges, 165.

Sclerenchyma, tissue consisting of long cells with narrow cavity and very much thickened cell-walls without any protoplasm, 49, 157.

Scorpioid cyme, a cymose inflorescence with the lateral branches developed alternately on opposite sides, 232.

Scutellum, the shield-like structure or cotyledon in the grains of grasses, 23.

Self-pollination, pollen of one flower reaching the stigma of the same flower or that of another flower on the same plant, 262.

Semi-parasite, a plant which derives part of its nourishment from another (host), 209.

Sepal, a segment of a calyx, 6.

Septicidal, opening along the septa, or lines of partition of a capsule, 286.

Septifragal, when the valves of the fruit break away from the septa,

Serrate, applied to the leaf-margin when toothed like a saw, 107.

Sieve-tubes, the rows of long tubes with perforated cross partitions (sieve-plates) found in the phloëm of a vascular bundle, 42.

Silique, an elongated pod having a false partition and opening by two sutures, usually found in Cruciferæ, 327.

Sorus, a spot or region in which spores are formed, a cluster of sporangia in the fern, 441.

Spadix, an inflorescence having a fleshy axis with numerous sessile flowers closely packed together, the whole surrounded by a common bract, 228, 417.

Spathe, the large bract enclosing the flowers of a spadix, 228, 237.

Species, a group of plants so much alike as may be called by the same name, 325.

Sperm-cells, the male reproductive cells, 444.

Spermaphytes, seed-bearing plants ; also called phanerogams, 1.

Spike, an inflorescence in which the flowers are sessile on a long axis, 228.

Spikelets, the small flower clusters of grasses enclosed by scaly bracts called glumes, 420, 423.

Spine, a sharp woody structure regarded as a modified leaf, branch or stipule, 82.

Sporangium, a case or sac containing spores, 441.

Spore, a reproductive cell which becomes free and capable of direct development into a new plant, 438.

Sporophylls, leaves bearing sporangia containing spores, 449.

Sporophyte, the generation which produces spores, 444.

Stamens, the male part of a flower having a filament and an anther, the latter producing the pollen, 7, 249.

Staminode, an aborted or rudimentary stamen, 242, 394.

Standard, the posterior petal of a papilionaceous corolla, 238, 248.

Stele, the central core of tissue and cells enclosed by the cortex stems and roots, 47, 93, 96.

Stigma, the topmost part of the pistil which receives the pollen, 7, 259.

Stimulus, an active agent existing outside the plant such as light, moisture, etc., producing definite changes in the plant, 424.

Stipe, the stalk which bears the pileus or cap of Agarics, 477.

Stipule, an appendage of the leaf found at the node on either side of the leaf base, 5, 114.

Stolon, branch disposed to root, 80.

Stomata, minute openings in the epidermis of leaves and young stems, which promote the gaseous exchange between the atmosphere and the interior of plants. 134.

Strophiole, an outgrowth on the hilum of some seeds, 291.

Suture, an apparent seam of union, or a line of dehiscence, 253.

Syconium (or fig), a multiple fruit formed of a hollow fleshy receptacle, inside which the fruits are placed, 288.

Sympodial, applied to the method of branching in which the main axis ceases to grow and the lateral branches form a false axis, 78.

Syncarpous, said of a fruit when the carpels are fused or united together, 253.

Synergids, the two nuclei found at the upper end of the embryo-sac by the sides of the egg-cell, 260.

Syngenesious, applied to anthers when they are united together so as to form a tube, the filaments being free, 249, 375.

Tap-root, the main root, the continuation of the radicle, 4.

Teleutospore, a resting two-celled spore of Uredineæ, a group of fungi, 473.

Tendrils, thread-like organs by means of which some plants cling on to their supports, 78, 81.

Testa, the hard outer coat of a seed, 291.

Tetradynamous, said of stamens when they are six in number, two of them being shorter than the rest, 250.

Thalamus, the receptacle or torus of the flower, 255.

Thallus, vegetative body having no distinction into leaf and stem, 438.

Thorn, a pointed woody structure regarded as a modified branch, 82.

Tissue, a combination of cells similar in origin and texture, 41.

Trama, a mass of hyphæ in the lamellæ of some fungi, from which the hymenium springs, 477.

Truncate, applied to the apex of a leaf when it is straight as though cut off, 127.

Tuber, a modified underground branch which is swollen and fleshy, 84.

Turbinate, shaped like a top or inverted cone.

Twiner, a plant which climbs or twines by winding their stems round their supporte, 80.

Twisted, contorted, 249.

Umbel, a flower cluster in which all the pedicels spring from the same point, 228.

Unit characters, define characters in the gamete which in heredity behave as indivisible entities, 492.

Utricle, a small thin-walled fruit, a fruit with thin loose pericarp, 402.

V

Vacuole, a cavity in the protoplasm of cells containing the cell-sap, 29, 41, 138.

Valvate, when sepals or petals meet together without overlapping, 248.

Vascular bundle, a group of conducting cells consisting of xylem and phloëm, 46.

Vegetative reproduction, propagation by vegetative means, e.g., cuttings, buds, etc., as opposed to sexual reproduction, 308.

Vein, one of the vascular bundles of a leaf usually appearing as a whitish green line, .

Velamen, layer or layers of absorbing cells found in the ærial roots of certain epiphytic orchids and aroids, 67, 436.

Ventral, pertaining to the side of a member which faces the axis from which it springs, in floral organs the side facing the centre of the flower, .

Versatile, applied to the attachment of the anther to its filament at a point so as to move freely, 251.

Verticillaster, a false whorl formed of many cymes congested together as in Leucas, 233, 401.

Vessel; a long tube produced by the breaking down of the cross walls in a row of cells.

Viviparous, giving rise to a new plant by germination or producing a bud, 412.

W

Whorl, arrangement at one plane around the stem, .

Wing-petal, the lateral petal of a papilionaceous corolla, 238, 248.

X

Xerophyte, plant adapted by its structure to a dry habitat, 426, 431.

Xylem, the wood portion of the vascular bundle, 49, 90, 159.

Z

Zygote, the cell resulting from the union of two gametes or male and female cell, 493.

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